NORTHEAST TEXAS SIP
APPENDIX A

Report - 'Ozone Modeling for the Tyler-Longview-Marshall Area of East Texas". November 12, 1999, Environ International

Ozone Modeling for the
Tyler-Longview-Marshall Area
of East Texas

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1. INTRODUCTION

BACKGROUND

The Texas Natural Resource Conservation Commission (TNRCC) operates three Continuous Air Monitoring Stations (CAMS) in the Tyler-Longview-Marshall (TLM) area of East Texas, as shown in Figure 1-1. These stations monitor compliance with the National Ambient Air Quality Standard (NAAQS) for ozone. In 1979, the NAAQS for ozone was set at 0.12 parts per million (ppm) averaged over 1 hour. In other words, an hourly average ozone reading of 125 ppb or higher exceeds the 1-hour ozone NAAQS. Whether or not an area is designated as being in nonattainment of the ozone NAAQS depends upon how frequently the standard is exceeded at any monitor. If the standard is exceeded four times in three years at one site, then an area is in violation of the standard and can be designated as nonattainment. In July 1997, the EPA announced a new ozone NAAQS based on an 8-hour averaging period. The average over a 3-year period of the annual 4th highest daily 8-hour maximum at any monitor is not to be greater than 0.08 ppm (85 ppb or higher). The new 8-hour ozone standard was challenged and is not being implemented at this time. Updated information on the ozone NAAQS can be found on EPA's web page at "http://ttnwww.rtpnc.epa.gov/naaqsfin/" and updated information on ozone nonattainment areas is available on EPA's web page at "http://www.epa.gov/oar/oaqps/greenbk/." The TNRCC also provides extensive information on issues related to ozone nonattainment via the WWW at "http://www.tnrcc.state.tx.us/homepgs/oaq.html."

In recent years, ozone levels measured in the Tyler-Longview-Marshall area have exceeded the levels of both the 1-hour and 8-hour standards. In 1996 the TLM area became a Flexible Attainment Region (FAR) and a mechanism for developing strategies to attain the 1-hour ozone standard was implemented under a Memorandum of Agreement *(Flexible Attainment Region Memorandum of Agreement, September 16, 1996)*. The TLM area has received funding from the Texas legislature to address ozone air quality issues through the "near non-attainment areas" program. These resources have funded studies through the East Texas Council of Governments (ETCOG) under the technical and policy direction of the North East Texas Air Care (NETAC) organization. In the 1996/97 funding biennium, NETAC sponsored important studies in to provide a better understanding of the conditions leading to high ozone concentrations. These studies examined the emissions inventory for the area as well as carrying out ambient monitoring. In 1998/99 biennium, these studies were extended through additional emission inventory development and ambient monitoring activities, plus the development of computer models to describe ozone formation in the TLM area. This report describes the development and application of photochemical ozone models for the TLM area of East Texas.

STUDY OBJECTIVES

The purpose of this study was to develop a photochemical ozone modeling system for the TLM area of East Texas. This will:

- Provide a better understand of the conditions leading to elevated ozone concentrations in the Tyler-Longview-Marshall area.
- Allow evaluation of the likelihood of future exceedances of the ozone NAAQS in the area.
- Provide a tool for evaluating the effects of alternative emissions reduction strategies in assuring that the area does not exceed the ozone NAAQS in the future.

The ozone models developed in this study have been applied to develop ozone control strategies for the TLM area under the direction of the NETAC Technical Committee.

MODELING STSTEM DESIGN

The main elements of the modeling system design were established early in the study through the "Modeling Protocol" and the "Episode Selection" analysis. These are separate documents available from the ETCOG:

- "Ozone Modeling Protocol for the Tyler/Longview/Marshall Area" dated 22 April, 1998.
- "Selection of episodes for East Texas photochemical model development" dated 7 October 1998.

The photochemical model selected for this study was the Comprehensive Air Quality Model with extensions (CAMx) version 2.0 available at http://www.camx.com. This is the model being used by the TNRCC to develop State Implementation Plans (SIPs) for other areas in Texas. CAMx contains all of the features in a state-of-the-science model such as two-way grid nesting and plume-in-grid treatment.

Three historical periods were selected for the modeling analysis:

- June 18-23,1995 – Regional Scale Model (RSM)
- July 7-12, 1995 – Regional Scale Model (RSM)
- July 14-18, 1997 – Urban Scale Model (USM)

All of these periods had high ozone concentrations in East Texas, as summarized in Table 1-1. For two of these periods (June 1995 and July 1995) there was previous regional scale modeling available that allowed the modeling planned this study to be expanded in scope from urban to regional scale. The third episode (July 1997) was modeled at an urban scale as originally planned.

Table 1-1. Ozone concentrations (ppb) at Longview and Tyler monitors during the periods selected for modeling.

	Longview		Tyler	
	1-hour	8-hour	1-hour	8-hour
6/18/95	77	72	78	68
6/19/95	89	85	99	88
6/20/95	145	110	109	100
6/21/95	108	101	100	95
6/22/95	120	102	97	94
6/23/95	145	103	96	93
7/7/95	130	98	77	63
7/8/95	74	68	77	72
7/9/95	71	68	67	64
7/10/95	85	79	78	76
7/11/95	123	99	85	82
7/12/95	111	88	90	80
7/14/97	106	79	56	NA[1]
7/15/97	86	60	72	52
7/16/97	139	87	59	NA[1]
7/17/97	104	91	83	73
7/18/97	117	103	91	85

[1] Not applicable because hourly ozone data were less than 75% complete at this site on this day.

Domain Definition

Following EPA's recommended procedures for defining a photochemical modeling domain, the following factors were considered:

- The typical wind patterns associated with elevated ozone episodes -- need for sufficient distance downwind from major sources to contain the ozone plume within the modeling domain as well as sufficient distance upwind of the area being studied to mitigate the influence of boundary conditions.

- The location of major sources – major sources should be located well within the modeling domain and the occurrence of major sources just outside of the modeling domain should be minimized.

- The locations of air quality monitoring sites and key receptor areas -- air quality monitoring sites and key receptor areas should be located away from the boundaries of the modeling domain; and

- The modeling domain should be defined to mitigate the effects of uncertainties in the upwind boundary conditions – major source regions should be located away from the boundaries of the modeling domain.

Avoiding excessive influence from boundary conditions is an important consideration in defining the horizontal extent of the modeling domain.. Performing regional-scale modeling is the most effective means of minimizing the influence of boundary conditions, hence it was considered a major technical advantage to be able to expand the scope of the modeling from urban to regional scale for two of three episodes.

Regional Scale Domain: The regional scale modeling domain is shown in Figure 1-2. The modeling grid consisted of an outer grid at 32 km resolution covering much of the southern US. The extent of the outer 32 km grid is the same as used in previous TNRCC modeling so as to allow this study to leverage off existing work. The 16 km grid (the first nested grid) covers an area of Texas and western Louisiana sufficient to cover all major source areas within a few hundred km of East Texas. The 4 km grid is centered on the TLM area and is the same size as the 4 km grid the urban scale domain, discussed below.

Urban Scale Domain: For the urban-scale modeling application, the TLM was modeled using a single 4 km grid system, i.e., no grid nesting, as shown in Figure 1-3. The 4 km grid was made large enough to include all major sources in areas immediately surrounding TLM. The 4 km grid is shown in Figure 1-3 superimposed on the 1993 elevated point source NOx emission inventory from an earlier TNRCC study. This 4 km grid provides a buffer of more than 100 km between the cities of Tyler and Longview and the domain boundary to account for upwind emissions and any re-circulation of air around the TLM area. The domain includes the nearby urban areas of Shreveport and Texarkana.

Vertical Layer Structure

The vertical layer structure for each modeling episode was tied to the layer structure used in the supporting meteorological model. This means that the layer structure differed between episodes, as shown in Table 1-2. In all cases there were at least 8 vertical layers which exceeds the EPA recommended minimum of five. The surface layer thickness was between 18 and 33 m, depending upon the episode.

Table 1-2. Vertical layer structures for CAMx.

Layer	June 1995 RSM		July 1995 RSM		July 1997 USM	
	Top	Thickness	Top	Thickness	Top	Thickness
12					3615	975
11					2640	814
10					1826	549
9			3641	749	1277	372
8	3030	910	2892	1078	905	263
7	2120	740	1814	690	642	255
6	1380	660	1124	442	387	126
5	720	340	682	288	261	90
4	380	160	394	183	171	69
3	220	140	211	110	102	51
2	80	60	101	68	51	33
1	20	20	33	33	18	18

Future Year

A year of 2007 was used to evaluate future ozone levels and control strategy effectiveness. The selection of the future year was made by the NETAC Technical Committee in consultation with the TNRCC and EPA. Currently, there are no regulations in place to drive the selection of any particular future year for modeling the TLM area, however, 2007 is the same year as the TNRCC is using for modeling other areas in Texas, and 2007 was also used by the EPA for ozone modeling of the entire eastern US.

Air Monitoring Sites in the Tyler-Longview-Marshall Area

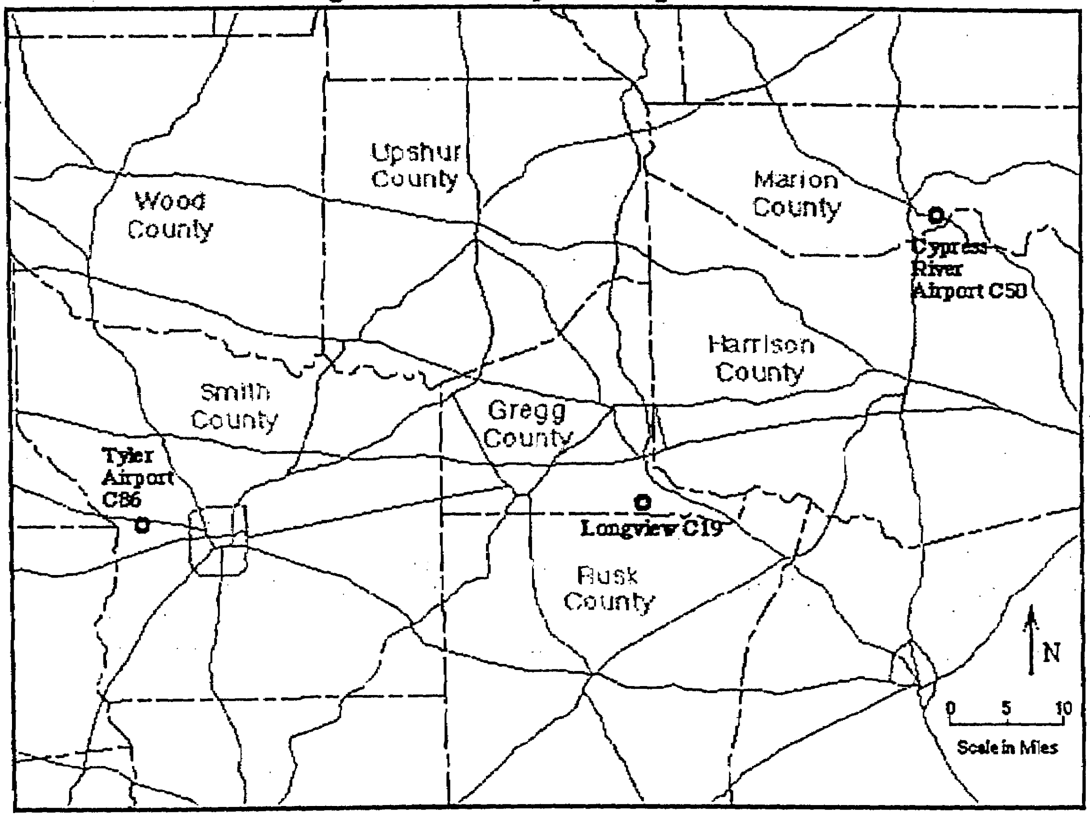
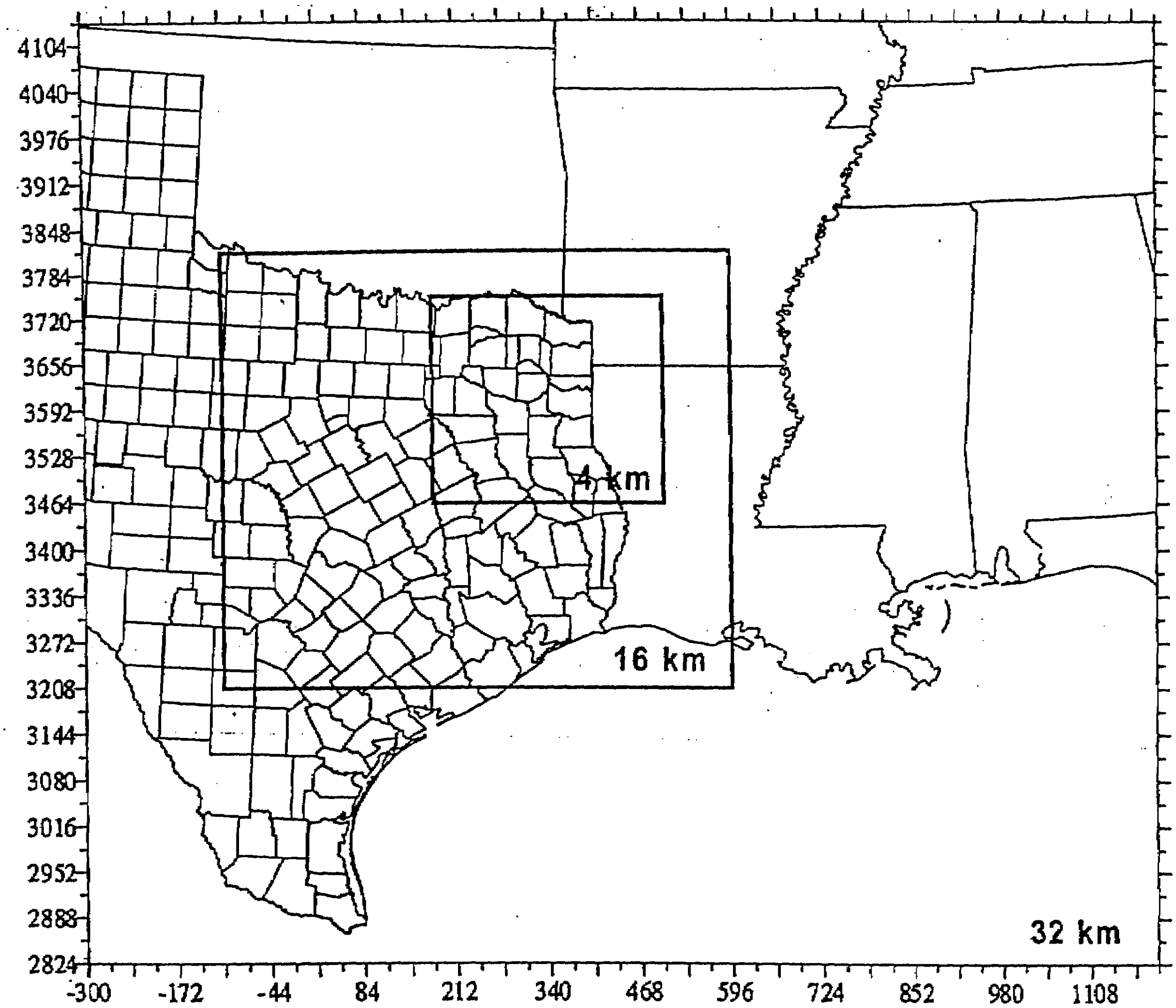


Figure 1-1. TNRCC Continuous Air Monitoring Sites (CAMS in the Tyler-Longview-Marshall area.



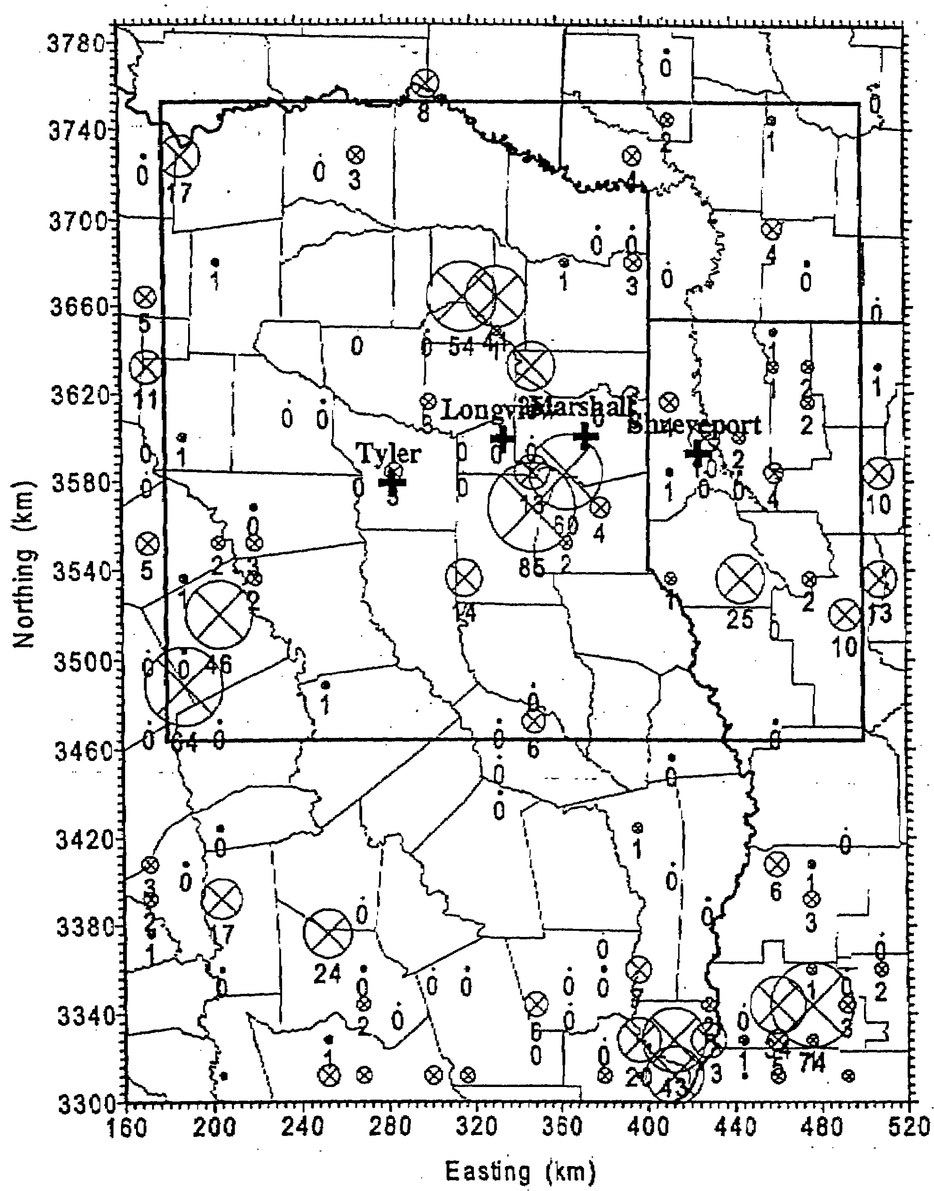
UTM Zone 15 Coordinates

32 km Grid: 47 x 41 32 km cells from (-300, 2824) to (1204, 4136)

16 km Grid: 44 x 38 16 km cells from (-108, 3208) to (596, 3816)

4 km Grid: 80 x 72 4 km cells from (180,3464) to (500, 3752)

Figure 1-2. Definition of the nested regional scale modeling domain.



UTM Zone 15 Coordinates

4 km Grid: 80 x 72 4 km cells from (180,3464) to (500, 3752)

Figure 1-3. Area of the urban scale model domain superimposed on an earlier (1993) TNRCC point source NOx emission inventory.

2. CAMx INPUT FILES

CAMx requires inputs to describe photochemical conditions, surface characteristics, initial/boundary conditions, emission rates, and various meteorological fields over the entire modeling domain. Table 2-1 summarizes the input data requirement for CAMx. Preparing this information requires several preprocessing/premodeling steps to translate "raw" emissions, meteorological, air quality and other data into final input files for CAMx. Input data preparation is most complex for the emissions and meteorological inputs, and so these are described separately in Sections 3 and 4. The remaining model inputs are described in this section.

Table 2-1. Overview of CAMx input data requirements.

INPUT DATA CLASS	DATA TYPES
Meteorology *Supplied by a Meteorological Model*	• 3-Dimensional Gridded Fields -Winds -Temperatures -Vertical Diffusivity -Pressure -Water Vapor -Cloud Cover -Rainfall
Air Quality *Obtained from Measured Ambient Data*	• Gridded Initial Concentrations • Hourly Gridded Boundary Concentrations • Time/space invariant Top Concentrations
Emissions *Supplied by an Emissions Model*	• Elevated Point Sources • Surface Sources -Low-level Point -Mobile -Area/non-road mobile -Biogenic Area
Geographic *Supplied by USGS Landuse Maps*	• Gridded Land Use/Surface Cover • Gridded Surface UV Albedo codes
Other *Ozone column from TOMS data* *Photolysis rates from radiative model*	• Vertical Grid Structure • Atmospheric radiative properties -Gridded haze codes -Gridded ozone column codes -Photolysis rates lookup table

MODEL OPTIONS

CAMx model options are specified through the model control file. The key portions of the control files for the RSM and USM applications are shown in Figure 2-1 and 2-2. The meaning of each parameter is indicated by the comment at the left of each line, and full details are given in the CAMx User's Guide (ENVIRON, 1998).

The following features were common to both the RSM and USM applications:

- The following (optional) major processes were considered: surface emissions, point source emissions, dry deposition and chemistry.
- The Smolarkiewicz horizontal advection option was used. This is the same as in CAMx modeling performed by the TNRCC for other areas (DFW and Houston).
- The plume-in-grid (PiG) option was used to model the early evolution of emission plumes from major NOx point sources. Individual PiG puffs were restricted to be less than 2000 m long and allowed to persist for up to 24 hours. The criteria for selecting which sources to treat with PiG are described in Section 3.

The differences between the RSM and USM applications are:

- Use of grid nesting for the RSM.
- Use of wet deposition for the USM, but not the RSMs. This is because rain and cloud fields were only available for the USM because only for the USM were the supporting meteorological model runs performed "wet" - see Section 4.

```
dtmx,dtin,dtem,dtou|0.5 1. 1. 1.
nx,ny,nz           |47  41  8
Coordinate ID      |UTM
xorg,yorg,dx,dy,zon|-300. 2824.  32.  32. -15
time zone          |5
PiG parameters     |2000. 24.
Avg output species |20
                   |O3         NO        NO2        PAN        NXOY       HNO3
                   |HONO       NTR       PAR        ETH        OLE        TOL
                   |XYL        FORM      ALD2       ISOP       MEOH       ETOH
                   |H2O2       CO
Num fine nest      |2
i1,i2,j1,j2,nz,mesh| 7 28 13 31 8 2
i1,i2,j1,j2,nz,mesh|16 25 21 29 6 8
SMOLAR or BOTT?    |SMOLAR
Restart            |false
Chemistry          |true
Dry dep            |true
Wet dep            |false
PiG submodel       |true
Staggered winds    |false
Treat area emiss   |true
Treat point emiss  |true
1-day emiss inputs |false
3-D average file   |false
Source Apportion   |false
```

Figure 2-1. CAMx model options specified in the control file for the regional scale model (RSM) applications.

```
dtmx,dtin,dtem,dtou|0.5 1. 1. 1.
nx,ny,nz           |80  72  12
Coordinate ID      |UTM
xorg,yorg,dx,dy,zon|180. 3464.  4.  4.  15
time zone          |6
PiG parameters     |2000. 24.
Avg output species |20
                   |O3         NO        NO2        PAN        NXOY       HNO3
                   |HONO       NTR       PAR        ETH        OLE        TOL
                   |XYL        FORM      ALD2       ISOP       MEOH       ETOH
                   |H2O2       CO
Num fine nest      |0
SMOLAR or BOTT?    |SMOLAR
Restart            |false
Chemistry          |true
Dry dep            |true
Wet dep            |true
PiG submodel       |true
Staggered winds    |true
Treat area emiss   |true
Treat point emiss  |true
1-day emiss inputs |false
3-D average file   |false
Source Apportion   |false
```

Figure 2-2. CAMx model options specified in the control file for the urban scale model (USM) application.

LANDUSE AND CHEMISTRY FILES

Landuse

The landuse data input to CAMx describe the surface characteristics and dominant vegetation type for each grid cell and are used in determining surface deposition rates. In addition, the landuse data are used in preparing the Albedo/Haze/Ozone Column input file described below. The landuse file specifies the fractional coverage (0 to 1) of 11 standard landuse types in each grid cell. These landuse types are listed in Table 2-2.

Table 2-2. Landuse categories for the CAMx landuse input file with associated surface roughness (m) and UV albedo values.

Category Number	Land Cover Category	Surface Roughness (meters)	UV Albedo
1	Urban	3.00	0.08
2	Agricultural	0.25	0.05
3	Rangeland	0.05	0.05
4	Deciduous forest	1.00	0.05
5	Coniferous forest including wetland	1.00	0.05
6	Mixed forest	1.00	0.05
7	Water	0.0001	0.04
8	Barren land	0.002	0.08
9	Non-forested wetlands	0.15	0.05
10	Mixed agricultural and range	0.10	0.05
11	Rocky (with low shrubs)	0.10	0.05

The United States Geological Survey (USGS) maintains a landuse database for much of the U.S., organized into 1:250,000 scale quadrant maps (200 m resolution) similar to their topographic database. Each 200×200 m "pixel" is assigned one of 37 landuse/land cover codes. All available maps covering the south central U.S. were downloaded directly from a USGS FTP site. A program was written to map the distribution of this high resolution data to each grid cell of the CAMx domain; the sum of area occupied by each landuse code in each cell was calculated and normalized to obtain fractional coverage. The USGS codes were then mapped to CAMx codes as shown in Table 2-3.

Table 2-3. Mapping of USGS to CAMx landuse codes.

CAMx	USGS
1 Urban	11 Residential
	12 Commercial and Services
	13 Industrial
	14 Transportation, Communication and Utilities
	15 Industrial and Commercial Complexes
	16 Mixed Urban or Built-up Land
	17 Other Urban or Built-up Land
2 Agricultural	21 Cropland and Pasture
	22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
	23 Confined Feeding Operations
	24 Other Agricultural Land
3 Range	31 Herbaceous Rangeland
	32 Shrub and Brush Rangeland
	33 Mixed Rangeland
4 Deciduous Forest	41 Deciduous Forest Land
5 Coniferous Forest and Wetland	42 Evergreen Forest Land
	61 Forested Wetland
6 Mixed Forest	43 Mixed Forest Land
7 Water	51 Streams and Canals
	52 Lakes
	53 Reservoirs
	54 Bays and Estuaries
8 Barren Land	71 Dry Salt Flats
	72 Beaches
	73 Sandy Areas other than Beaches
	74 Bare Exposed Rock
	75 Strip Mines, Quarries, and Gravel Pits
	76 Transitional Areas
	77 Mixed Barren Land
9 Nonforest Wetland	62 Nonforested Wetland
10 Mixed ag and Rangeland	None
11 Rocky with low shrubs	81 Shrub and Brush Tundra
	82 Herbaceous Tundra
	83 Bare Ground
	84 Wet Tundra
	85 Mixed Tundra

Photolysis Rates

The photolysis rates input file describes the relationship between photolysis reactions (reactions initiated by sunlight) and key environmental parameters, namely, solar zenith angle, altitude, surface UV albedo, turbidity (haze) and the stratospheric ozone column. This input file was prepared using version 3.6 of the Tropospheric Ultra-violet/Visible TUV radiation model. TUV is a state of the art solar radiation model distributed by the National center for Atmospheric Research (NCAR) via the WWW at "http://acd.ucar.edu/~siri/tuv.html." A version of TUV that is compatible with CAMx is available from the CAMx web site at "http://www.camx.com."

Albedo/Haze/Ozone Column

The Albedo/Haze/Ozone Column input file is used by CAMx to determine which photolysis rates to use for each model grid cell at each time step. The surface UV albedo for each model grid square was calculated using the landuse data from the CAMx landuse file, described above, together with the UV albedo values for each landuse type given in Table 3-2. Since no data were available on the atmospheric turbidity due to aerosols during the study periods, an optical depth due to aerosols of 0.084 was assumed which is representative of rural environments. Ozone column data were derived from data recorded by NOAA's TIROS Operational Vertical Sounder (TOVS) satellite available via the WWW at "http://nic.fb4.noaa.gov/products/stratosphere/tovsto/."

Chemistry Parameters

The chemistry parameters file defines the chemical mechanism for the simulation. CAMx can be used with several versions of the Carbon Bond 4 (CB4) mechanism, as discussed in the CAMx User's Guide (ENVIRON, 1998). For this study, CAMx mechanism number 3 was used. This is the CB4 mechanism with updates to the isoprene chemistry and radical-radical termination reactions. This is must up-to-date version of CB4 available and is the mechanism recommended for use by ENVIRON. The default chemistry parameters file for mechanism 3 distributed with CAMx by ENVIRON was used.

INITIAL AND BOUNDARY CONDITIONS

Boundary conditions (BCs) are the concentrations of ozone and precursors specified at the edge of the CAMx modeling domain. Thus, when the wind blows into the CAMx domain across a boundary, air enters CAMx containing the pollutant levels specified by the boundary conditions. The boundary conditions are specified for each species tracked in model (e.g., ozone, NO, NO_2, individual VOCs, etc.). In CAMx, the boundary conditions for a single pollutant may be held constant around all the boundaries everywhere, all the time, or they can be allowed to vary in time and/or geographically. The degree to which the BCs will impact CAMx predictions for the Tyler/Longview/Marshall (TLM) area depends upon how far the boundaries are from TLM. Thus, BCs will generally have more impact in the Urban Scale Model (USM) than the Regional Scale Models (RSMs). The USM and RSM domains are shown in Section 1.

The most obvious approach to developing BCs is to base them on data observed at monitors located near the boundaries of the modeling domain. In practice, this is generally difficult because ozone monitors are quite far apart. In addition, when we design the model domains we often try to locate model boundaries away from major sources (e.g., major urban areas) where monitors tend to be located. Also, note that monitors only measure concentrations at the surface whereas the CAMx model typically extends up to 3 or 4 km above the surface. These factors make it difficult to develop BCs from observed data. The availability of suitable monitoring data for precursors (NOx and VOCs) is even more limited than for ozone.

EPA Default BCs

Given the difficulty in obtaining data to develop BCs simple default values are often used. In the 1991 EPA "Guideline for Regulatory Application of the Urban Airshed Model" the following default values are recommended:

Table 2-4. EPA Default Values for Boundary Conditions (EPA, 1991)

	Concentration (ppb)
O3	40
NOx	2
VOC	22.1
CO	350

The EPA guidance breaks out the VOCs into the individual compounds used in the Carbon Bond mechanism, but they are summarized here as total VOC for simplicity and to aid comparison.

More recently (in 1995) the following boundary conditions were used in the regional ozone modeling performed by the Ozone Transport Assessment Group (OTAG):

Table 2-5. OTAG Values for Boundary Conditions

	Concentration (ppb)
O3	34.6
NOx	0.1
VOC	4.4
CO	100

Comparing Tables 2-4 and 2-5 shows that the OTAG BCs were lower than the EPA recommended default values. This is because the OTAG boundaries were located in rural or remote areas such as the Rocky Mountains, Canada, the Atlantic Ocean and the Gulf of Mexico, whereas the EPA default values were intended for urban scale model domains within populous areas of the continental US.

TNRCC Regional Modeling

The TNRCC has performed regional scale modeling for episodes in 1993, 1995 and 1996 on a domain covering essentially the same area as the RSM. The 1993 episode was modeled first (Yocke, et al., 1996) with the 1995 and 1996 modeling building from this study. During the development of the 1993 TNRCC RSM several databases were reviewed and evaluated, including: the EPA UAM default boundary conditions (EPA, 1991); measurements at the Kinterbish, AL and Niwot Ridge, CO rural/remote sites (Goldan et al., 1995; Watkins et al., 1995); and boundary conditions used in the Gulf of Mexico Air Quality Study (GMAQS) and OTAG regional modeling studies.

For the TNRCC RSM, the lateral boundaries were divided into three segments as shown in Figure 2-3.

The boundary conditions used for these segments were as follows:

Table 2-6. Summary of boundary conditions (ppb) for the TNRCC regional modeling studies

	Lateral Boundary Segment		
Species	Northeast	West	South
Ozone	41	40	40
NOx	1.1	1.1	0.51
VOC	50.5	22.3	9.3
CO	200	200	100

For the TNRCC regional modeling studies, interpolated ozone measurements were used for the Northeast boundary segment, i.e., the ozone along the northeast boundary varied with location and time. The value of 41 ppb shown in Table 2-6 is the average concentration along the Northeast boundary segment below about 2000 meters over the period June 18-22, 1995.

Modeling results from the TNRCC regional modeling can be used to characterize BCs for the East Texas Urban Scale domain. We have analyzed CAMx results from the 1995 base case for the June 18-22, 1995 episode used in regional modeling of the Dallas/Fort-Worth area. The average concentrations predicted around the perimeter of the East Texas USM domain are:

Table 2-7. Summary of average concentrations around the boundary for the East Texas USM domain below about 2000 m AGL for June 18-22, 1995

	Concentration (ppb)
O3	59.3
NOx	0.50
VOC	54.8
CO	178

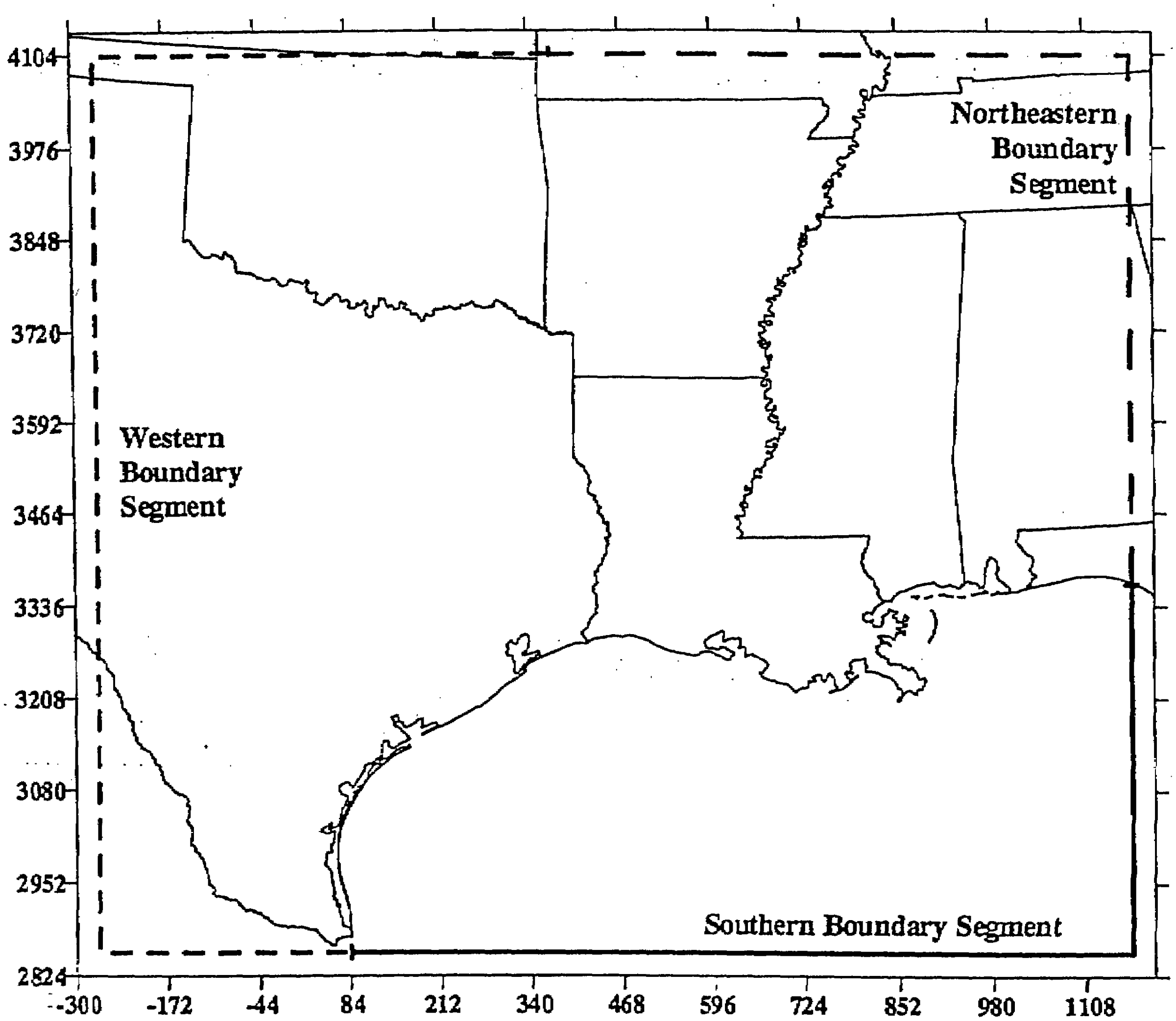


Figure 2-3. Definition of boundary segments for the regional scale modeling domain.

Boundary Conditions for the Regional Scale Models

The RSM boundary conditions were developed to be consistent with previous TNRCC regional modeling as summarized in Table 2-6. Complete details of these boundary conditions for all modeled species are shown in Table 2-8. The values shown in Table 2-8 were used for the lateral boundary conditions for all CAMx layers below approximately 2,000 meters above ground level (m AGL). With the exception of ozone along the Northeast segment, these are exactly the same as used in the TNRCC regional modeling of the 1993 episode (Yocke, et al., 1996). Above approximately 2,000 m AGL, the clean values shown for the South boundary segment in Table 2-8 were used. These clean South boundary values were also be used for the top boundary of the model, as in previous TNRCC regional modeling.

As noted above, the only difference between the values proposed in Table 2-8 and the earlier TNRCC studies is use of a constant ozone boundary condition of 41 ppb for the Northeast boundary, whereas the TNRCC interpolated ozone concentrations along this boundary from monitored values. The proposed approach of using 41 ppb is justified given the large distance between northeast boundary and East Texas.

Table 2-8. Proposed RSM boundary concentrations for each lateral boundary segment (ppb) below the afternoon maximum mixing height (below approximately 2,000 m AGL).

	Lateral Boundary Segment		
Species	Northeast	West	South
Ozone	41	40	40
CO	200	200	100
NO	0.1	0.1	0.01
NO2	1	1	0.5
NXOY	1.00E-04	1.00E-04	1.00E-04
HNO3	0.001	0.001	0.001
HONO	0.001	0.001	0.001
ALD2	0.555	0.555	0.05
ETH	0.51	0.51	0.15
FORM	2.1	2.1	0.05
OLE	0.3	0.3	0.05
PAR	14.94	14.94	7.6
TOL	0.18	0.18	0.0786
XYL	0.0975	0.0975	0.0688
ISOP	3.6	0.1	0.001
CRES	0.001	0.001	0.001
MGLY	0.001	0.001	0.001
OPEN	0.001	0.001	0.001
PAN	0.001	0.001	0.001
PNA	0.001	0.001	0.001
H202	0.001	0.001	0.001
MEOH	8.5	1.00E-06	1.00E-06
ETOH	1.1	1.00E-06	1.00E-06

Final Boundary Conditions for the USM

As described in Section 5, base case diagnostic testing and model performance evaluation for the July 1997 USM showed that the BCs in Table 2-7 were too high. For the final July 1997 base case, clean BCs were used as shown for the western boundary in Table 2-8.

Initial Conditions

The initial conditions (ICs) are the concentrations specified throughout the CAMx domain at the beginning of the model run. The ICs have most impact at the start of the model run (on the first day) and become less important as the run progresses. The main reason for running "spin-up" days before the start of each episode is to reduce the impact of the ICs. There were at least two spin-up days for each episode. Thus, the exact values chosen for ICs should not be important and the preferred approach is to select fairly "clean" ICs that are appropriate for the area. Thus, for both the USM and RSMs, the ICs were set to the relatively clean values shown for the Western boundary segment in Table 2-8.

FUTURE YEAR INITIAL AND BOUNDARY CONDITIONS

Since all of the final base year base cases used clean values for the ICs and BCs, there was no need to change these values for the future year scenarios. Thus, all future year modeling was conducted with the same clean IC/BCs as the final base year base case modeling.

3. METEOROLOGICAL MODELING

INTRODUCTION

CAMx requires meteorological information to describe the dispersion of pollutants in the atmosphere, which is treated as the combination of advection by grid-resolved mean winds and diffusion (mixing) by sub-grid scale turbulence. Meteorology also influences other important processes in CAMx, such as chemical rates, deposition rates, and point source plume rise. In order to describe these processes CAMx requires hourly, three-dimensional gridded inputs for the following parameters:

- vertical layer interface heights (m)
- vector component (east-west vs. north-south) winds (m/s)
- temperature (K)
- pressure (mb)
- water vapor mixing ratio (ppm)
- vertical turbulent exchange coefficient or diffusivity (m^2/s)
- fractional cloud cover (optional)
- cloud liquid water content (optional)
- rainfall rate (optional)

These CAMx input fields are developed using some type of meteorological model as a "pre-processor." Strictly speaking, layer interface heights are not meteorological parameters, but these are needed to define the spatio-temporal variation of the CAMx vertical grid system so that the air quality model can be properly interfaced to the grid system of almost any meteorological model that is used to supply the input fields. This helps to maintain physical consistency between the driving meteorological inputs and the air quality model. There are two general classes of meteorological models: diagnostic and prognostic.

Diagnostic and Prognostic Models

Diagnostic meteorological models develop 3-D meteorological fields by performing spatial and temporal interpolation of available observations and calculating other variables that are not directly measured. Thus, diagnostic models are limited by the information available in the observational data. This is a serious limitation for ozone modeling and the use of diagnostic models has largely been discontinued. The availability of observational data is most limited for the characterization of winds aloft and the extent of vertical mixing in the atmosphere – both of which are critical for ozone modeling. Another problem with diagnostic models is their limited ability to constrain meteorological fields to be in physical balance, i.e., for wind, temperature and pressure fields to be internally consistent. This is a problem for modern air quality models such as CAMx, which are designed to work with hydrodynamically balanced fields.

Prognostic meteorological models are essentially numerical weather forecasting models. They predict meteorological fields by solving equations of motion and thermodynamics, which describe the evolution of winds, temperature, moisture, and pressure in response to numerous forces at many scales. Computational approaches differ between models, with some models making more simplifying assumptions than others. The fifth-generation PSU/NCAR Meteorological Model (MM5) and the Regional Atmospheric Modeling System (RAMS) are the most advanced prognostic meteorological models in widespread use for air quality modeling. The Systems Applications International Meteorological Model (SAIMM) is a less advanced model because it makes more simplifying assumptions. The MM5 is a publicly available model whereas a license fee must be paid to use RAMS or SAIMM.

An important advance in prognostic meteorological models is the ability to incorporate observational data into the model solution, called four dimensional data assimilation (FDDA). FDDA allows the meteorological model fields to be guided (nudged) toward observational analyses in an effort to reduce the degree by which the model "drifts" from the conditions that were actually measured. MM5, RAMS and SAIMM all have the FDDA capabilities.

Meteorological Modeling Approaches Employed in This Study

The regional ozone air quality modeling undertaken for this study leveraged off of two meteorological modeling databases that had been developed in previous air quality modeling programs. New meteorological modeling was performed for the July 1997 ozone modeling. There is no conceptual problem in basing CAMx modeling on the products from three different meteorological models; the model-specific input fields for a given episode are just a single possible "realization" of the meteorology that occurred, and are evaluated based on the qualities of model performance. The models employed for each episode were:

- SAIMM for the June 18-23, 1995 RSM
- RAMS for the July 7-12, 1995 RSM
- MM5 for the July 14-18, 1997 USM

The first episode had been modeled previously by the TNRCC for the Dallas/Fort-Worth (DFW) area using SAIMM (TNRCC, 1998). The TNRCC modeled the full extent of the regional 32-km UTM domain at 16-km resolution, and the DFW area at 4-km resolution. The second episode had been modeled previously by OTAG using RAMS3a applied to the entire eastern U.S. (OTAG, 1996). RAMS3a was run on a 108/36/12-km polar stereographic grid system, with the 36-km grid covering the eastern two-thirds of Texas, and the southwest corner of the 12-km grid extending into northeast Louisiana. The third episode represents the only original meteorological modeling performed in this study, as no existing database was available for this period. The MM5 is the most advanced, state-of-the-science, multi-scale/multi-grid prognostic meteorological model publicly available. The MM5 Lambert conformal grid projection was configured to match the CAMx 4-km UTM grid as closely as possible.

This section describes the processes by which meteorological data from these three independent modeling approaches were translated to CAMx inputs. For the RSM episodes, the specific configurations and operating methodologies employed for the SAIMM and RAMS3a applications are referenced to the appropriate literature, while the supplementary MM5 application developed for the USM episode is fully described herein. A summary of meteorological model performance in the East Texas area is also provided for each episode.

JUNE 18-23, 1995 RSM

The East Texas episode selection identified June 20 and 23 as days representative of stagnation conditions. This episode period was previously modeled for the DFW area by the TNRCC and the meteorology is described in TNRCC (1998). The TNRCC analysis also characterized this period as stagnation conditions.

Meteorological conditions in East Texas during this episode were influenced by an overall high pressure ridge aloft, with an imbedded low pressure system to the east over Georgia and Alabama. Winds aloft were generally light and from the north, except on June 20 and 21, when the low intensified, moved slightly westward, and strengthened the northerly winds aloft. At the surface, local conditions were affected by high pressure over the entire central/eastern U.S. Flat pressure gradients over the south-central U.S. resulted in stagnation conditions, with light and variable surface winds, generally clear skies, and no precipitation. Daily maximum temperatures for this period ranged from 91 to 94°F.

Meteorological Modeling Methodology

CAMx meteorological inputs were developed from TNRCC SAIMM meteorological model fields that were originally produced for the DFW CAMx applications. The DFW CAMx modeling covered the period June 18-22, but TNRCC had also performed SAIMM modeling for June 23. Thus, SAIMM fields were available for the full episode period being modeled for East Texas.

The TNRCC applied the SAIMM on the full extent of the 32-km UTM regional domain at 16-km resolution, from which a "master" set of DFW CAMx inputs were developed. Grid-specific CAMx inputs were then derived from this master by aggregating up to the 32-km resolution of the regional grid, and windowing out the intermediate 16-km Texas grid. The TNRCC also ran the SAIMM independently at 4-km resolution over the DFW area (SAIMM has no 2-way nesting capabilities). However, the TNRCC experienced problems with inconsistencies between the 4- and 16-km fields at the edges of the smaller grid which required using a smoothing technique near the 4-km grid boundaries (TNRCC, 1998).

In this study, the inputs for the 32- and 16-km UTM East Texas CAMx grids were derived from the master DFW CAMx 16-km fields similarly to the approach described above. However, the 4-km DFW grid did not extend sufficiently eastward to cover East Texas. For this reason, and in light of the technical problems encountered by TNRCC described above, the SAIMM was not run at 4-km resolution over East Texas. Instead, the meteorology for the 4 km grid was interpolated from the master 16-km fields. TNRCC meteorologists reviewed the 16 km SAIMM model output in the area of East Texas and found that the predicted wind fields were smooth in this area (Bob Cameron, personal communication). This was to be expected because there are were no factors that would tend to introduce high resolution features into the meteorological fields in this area for this episode (e.g., frontal passages, complex terrain, or isolated convection). Thus, the interpolation approach was considered technically reasonable.

Since the vertical layer structure had been defined by TNRCC in the development of the master 16-km DFW CAMx fields, this same structure was used for all grids in the East Texas modeling (Table 3-1).

Table 3-1. CAMx layer structure for the June 1995 regional scale model

Layer	June 1995 RSM	
	Top	Thickness
8	3030	910
7	2120	740
6	1380	660
5	720	340
4	380	160
3	220	140
2	80	60
1	20	20

The TNRCC ran the SAIMM in a dry mode with no clouds or precipitation. Thus, no cloud cover or rainfall files were developed for the CAMx simulation of this episode. This should not have a major impact on the ozone modeling as this period was characterized by high pressure with relatively clear skies.

Results and Model Performance

The TNRCC has previously evaluated the performance of the SAIMM in simulating the meteorology for this episode as part of the ozone modeling for the DFW area (TNRCC, 1998). Briefly, the TNRCC found that the "meteorological fields were found to be representative and consistent with the raw meteorological data." Some noted concerns related to SAIMM's tendency to under predict peak surface temperatures by 2-3 °C. A similar bias was found in our analysis of the SAIMM temperature fields when developing biogenic emission inputs, as described in Section 4. TNRCC also noted a tendency for turbulent vertical mixing (Kv values) in the lower atmosphere to drop sharply in the late afternoon about two hours earlier than expected, and stated that "this feature is inherent in the model formulation for SAIMM".

However, since vertical mixing and surface temperature are strongly coupled, it is common that shortcomings in one component leads to deficiencies in the other. Overall, the TNRCC found that these artifacts did not adversely effect ozone predictions for the DFW area.

The focus of the performance evaluation described here is the ability of the SAIMM to describe the meteorology in the TLM area. This was evaluated using the meteorological observations recorded at the Gregg County Airport (site GGGC).

Surface Wind Speeds

The observed and modeled surface wind speeds at GGGC are compared in Figure 3-1. Wind speeds were low throughout this period consistent with the stagnant conditions. SAIMM generally reproduces the diurnal pattern of low surface wind speeds at night and higher wind speeds during the day. A scatter plot of the modeled against observed wind speeds (Figure 3-2) shows a tendency to over-predict the lowest wind speeds below 0.5 m/s. It is not surprising for SAIMM to over-predict the very stagnant near-zero wind speeds since such models tend to "over-organize" stagnant flow fields. When observed winds below 0.5 m/s are excluded (Figure 3-3) the least squares line approaches the desired 1:1 relationship, but with considerable scatter in modeled-observed pairs. The SAIMM does not show a statistically significant over- or under-prediction bias in wind speeds at the GGGC site.

Surface Wind Direction

The observed and modeled surface wind directions at GGGC are compared in Figure 3-4 for hours when the observed wind speed was greater than 0.5 m/s. Hours with wind speeds at or below the measurement reporting threshold of 0.5 m/s are excluded because observed wind direction has little meaning and tends to be erratic at 0.5 m/s. Figure 3-4 shows that SAIMM generally tracked the change in wind direction from easterly during the day on June 18 to northerly on June 21 and 22. However, wind directions tend to differ by as much as 60° on June 21 and 22. Large scatter is seen on June 23 associated with the very light wind speeds measured on that day.

Boundary Layer Depth

The depth of rapid vertical mixing during the day can play an important role in ozone formation. The well mixed portion of the atmosphere near the earth's surface during the day is often referred to as the planetary boundary layer (PBL). CAMx represents the atmosphere using a series of layers and for this study the layer depths are shown in Table 3-1. Mixing between each layer is described by an exchange coefficient (Kv) which varies in space and time. However, it is difficult to evaluate Kv values and interpret the degree of vertical mixing, so we have developed a methodology from which to approximate PBL depths from the Kv fields and the model layer structure. A time series of this approximation is shown in Figure 3-5 for the GGGC site. The mixing heights are calculated at each hour to the nearest layer interface, hence the step ladder appearance in the figure.

The PBL depth starts low in the morning and then grows as solar heating of the Earth's surface causes turbulent mixing. The PBL depth reaches a maximum in the mid afternoon. Figure 3-5 suggest only minor differences in PBL depth/vertical mixing at the GGGC site over the period June 20-23. This is consistent with the fact that all of these days are characterized by similar stagnant conditions. Note the consistent 200 m mixing depth at night, which is a result of the fact that TNRCC artificially increased Kv values in the lowest two layers (to account for the effects of mechanical mixing) when they developed the master 16-km CAMx inputs. We do not have any useful information to evaluate the modeled vertical mixing; the standard NWS soundings at GGGC are taken in the morning and evening and so are not useful to evaluate the evolution of deep mixing during the critical late-morning and mid-day period.

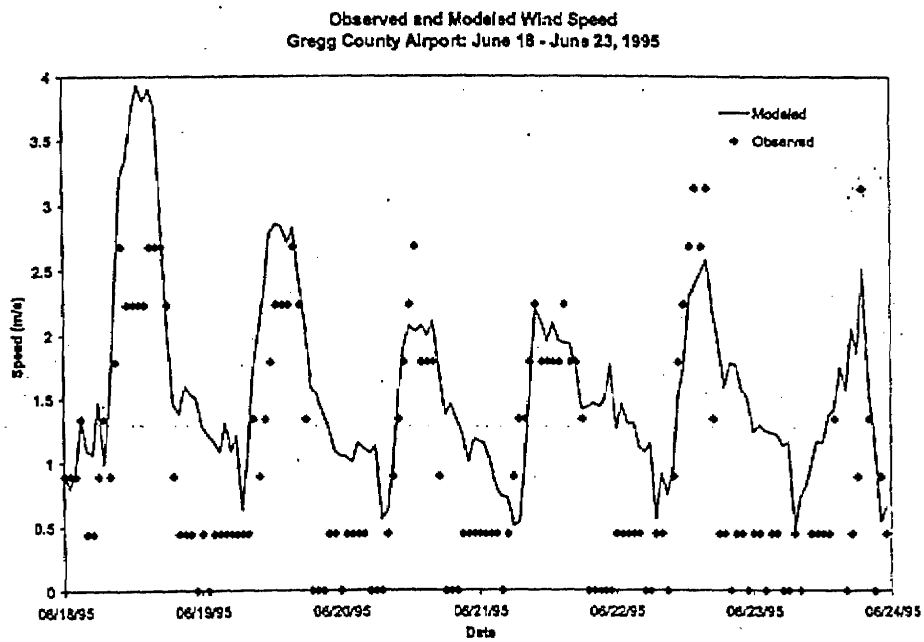


Figure 3-1. Time series of SAIMM-modeled and observed surface wind speeds at the Gregg County Airport on June 18-23, 1995.

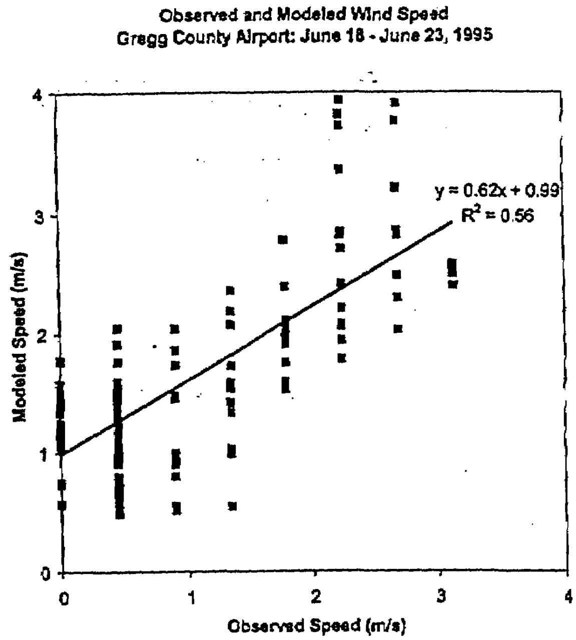


Figure 3-2. Scatter plot of SAIMM-modeled and observed surface wind speeds at the Gregg County Airport on June 18-23, 1995.

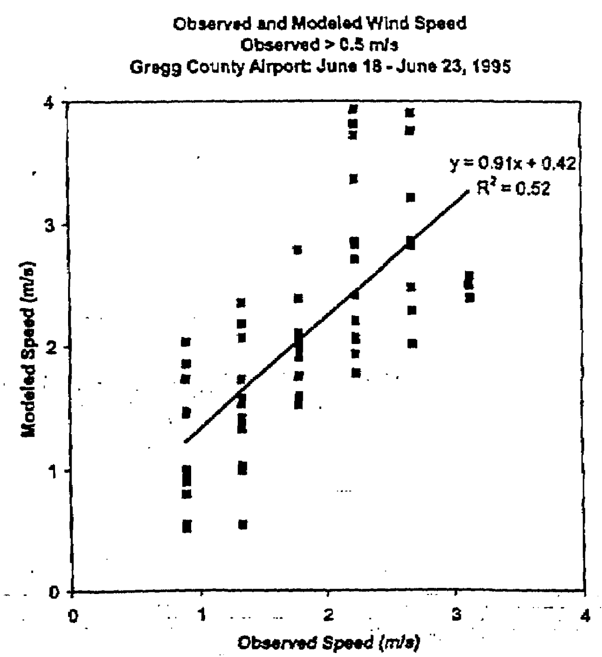


Figure 3-3. Scatter plot of SAIMM-modeled and observed surface wind speeds at the Gregg County Airport on June 18-23, 1995 for observed winds speeds greater than 0.5 m/s.

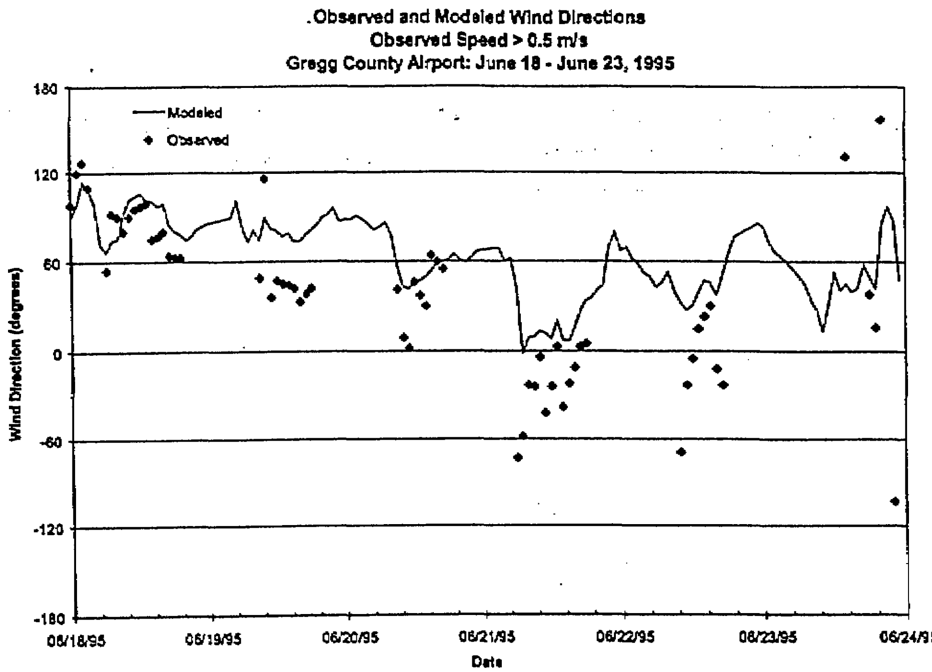


Figure 3-4. Time series of SAIMM-modeled and observed surface wind direction at the Gregg County Airport on June 18-23, 1995 for observed winds speeds greater than 0.5 m/s.

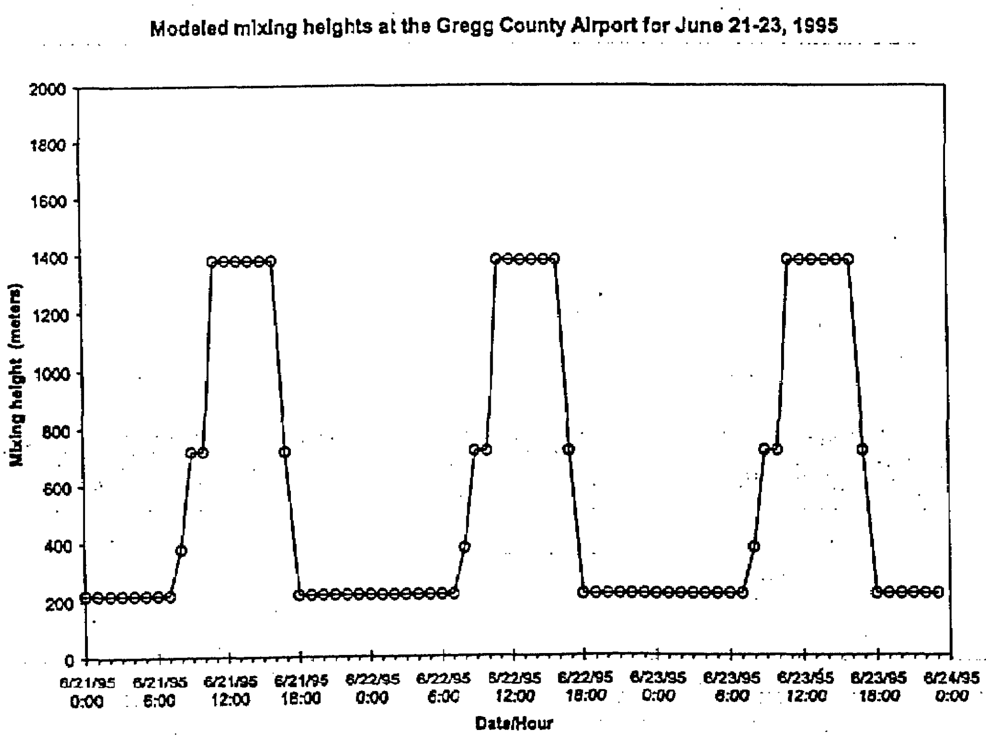


Figure 3-5. Approximated PBL depth at the Gregg County Airport on June 21-23, 1995, derived from CAMx input fields of vertical diffusion coefficient.

JULY 7-12, 1995 RSM

The key episode days during this period were July 11 and 12 when ozone levels were high. Ozone on the previous two days remained at moderate levels.

Meteorological conditions in East Texas during this period were influenced by the presence of a strong high-amplitude upper-air ridge centered over the Rocky Mountains for much of the period. With generally weak pressure gradients aloft and at the surface, high pressure prevailed over the East Texas area with weak stagnant flow at the surface and moderate northeasterly winds aloft. The episode days coincide with the slow movement of the upper-air ridge eastward into the central plains, which further stabilized the atmosphere over East Texas. As a result, skies remained cloud free and daily maximum temperatures ranged from 96 to 99°F throughout the period.

Meteorological Modeling Methodology

For several years, the Alamo Area Council of Governments (AACOG) have utilized OTAG RAMS3a meteorological fields for the development of UAM-IV and CAMx inputs. A significant ozone event occurred in that area during July 10-12, 1995, which is contained within the OTAG July 1995 modeling period. For the East Texas study it was decided that these RAMS3a fields could be utilized in a similar fashion for the July 1995 RSM.

The OTAG meteorological modeling was performed by the Wisconsin Department of Natural Resources (WDNR). RAMS3a was configured to run on a system of nested grids spanning most of the North American Continent on a polar stereographic projection. The outermost mesh had a grid spacing of 108 km; an intermediate 36-km grid covered the eastern U.S., while a fine 12-km mesh was positioned to cover the major transport routes between the midwest and east coast. Relative to East Texas, the 36-km grid extends over the eastern two-thirds of the state, and the southwest corner of the 12-km grid extends into northeast Louisiana. Therefore, the RAMS3a 36-km grid provides adequate coverage of the entire RSM domain. The RAMS3a vertical layer structure resolves the boundary layer and troposphere with more than 30 layers between the surface and an altitude of about 16 km. FDDA was utilized throughout the simulation to minimize model drift. The model was run dry, so no clouds or precipitation processes were simulated.

The overall approach to develop RSM meteorological inputs was to interpolate the 36-km polar stereographic RAMS3a fields to the 32-km UTM regional domain, from which the 16- and 4-km fields were then extracted via additional interpolation. The specific steps involved in processing the OTAG RAMS3a meteorological output to the 32/16/4-km East Texas grid structure include:

1) Processing of the RAMS3a meteorological variables to the CAMx variables;
2) Interpolation of the processed meteorological variables from the 36-km polar stereographic grid to the 32-km UTM regional grid;
3) Interpolation of the 32-km UTM fields to the 16- and 4-km UTM nested grids;

The RAMSCAMx conversion program was used for steps 1 and 2. A version was developed to translate the specific formats of the OTAG RAMS3a output data to the parameters and formats required by CAMx. Table 3-2 illustrates the gridded meteorological parameters required by CAMx, and the RAMS variables from which they are derived. In the table, z_g represents the topographic elevation, z_s is the layer height structure above sea level, and z_{top} is the RAMS3a model top (16391.06 m). For those parameters in which fields are developed for the coarse grid only, it was left for CAMx to internally interpolate these to all fine grids. As a way to limit the degree of error associated with vertical aggregation of meteorological data to the relatively coarse CAMx layer structure, we defined CAMx layer interface heights to match a subset of RAMS layer interfaces instead of specifying a constant height grid. These heights expand and contract spatially as a function of underlying terrain heights (see Figure 3-6 for an illustration of the vertical height grid at sea level). Since the height grid is time-invariant, the layer interface heights are calculated when the first hour of data are read.

Table 3-2. Relationship between RAMS3a and CAMx gridded meteorological parameters.

CAMx variable	RAMS variable(s)
Layer interface height (m)	Z_g (m), z_s (m), z_{top} (m)
u-component (east/west) wind (m/s)	u-component wind (m/s)
v-component (north/south) wind (m/s)	v-component wind (m/s)
Temperature (K)	Temperature (C)
Water Vapor (ppm) (coarse grid only)	Water vapor mixing ratio (g/kg)
Pressure (mb)	Pressure (mb)
Vertical Diffusivity (m^2/s)	Temperature (C), winds (m/s), pressure (mb), water vapor (g/kg)

In RAMSCAMx, the three-dimensional prognostic variables are "coupled" to atmospheric density after they are read in. This allows the horizontal interpolation and vertical aggregation of all variables to be conducted on a mass-weighted basis. Variables are de-coupled before they are written to CAMx files. RAMSCAMx also performs a wind rotation calculation to account for the different definitions of "grid north" between the specific polar stereographic projection defined in the OTAG modeling and the UTM coordinates used here. Since no cloud or rain processes were simulated with RAMS3a, these optional CAMx input fields were not produced in this study. This should not have a major impact on the ozone modeling as this period was characterized by high pressure with relatively clear skies.

Vertical diffusion coefficients are provided in the OTAG RAMS3a output. However, it is not clear how these were generated; either (1) version RAMS3a directly output vertical diffusion coefficients and these were carried over in the processing performed by WDNR, or (2) the diffusivities were calculated by WDNR from the raw hourly meteorological fields during the processing of these files. In any event, inspection of these diffusivity fields indicated very low values throughout the day, as much as an order of magnitude lower than is typically produced in daytime convective boundary layer models. We have noted that diffusivities produced by RAMS in past air quality applications have been similarly low, which suggests that the values in the OTAG RAMS3a files were directly output from the model. These vertical diffusivity fields were determined to be inadequate for the purposes of the CAMx modeling in East Texas.

No turbulent kinetic energy (TKE) information is available in the OTAG RAMS3a output from which to derive vertical diffusivity values. Therefore, it was necessary to find an alternative first-order diagnostic approach to develop vertical diffusivity fields from the hydrodynamic variables. After several approaches were evaluated, the McNider and Pielke (1981) model was selected for RAMSCAMx since it maintained an appropriate diurnal cycle in the magnitude of diffusivity and effective boundary layer depths. A minimum value of 0.1 m^2/s is imposed.

Step 3 in processing the RAMS3a output for CAMx was accomplished using a windowing/interpolation program similar to that employed in the June 1995 RSM preprocessing, which mapped meteorological parameters on the "master" DFW CAMx 16-km grid to the 4-km East Texas grid. In this case, however, the program was used to map the CAMx fields processed on the 32-km regional grid to both the 16- and 4-km nests.

RAMS Layer Interface Heights		
k	height	CAMx Layer Interface Heights
19	3641.06	---9---
18	2892.39	---8---
17	2293.45	
16	1814.30	---7---
15	1430.98	
14	1124.33	---6---
13	879.00	
12	682.74	---5---
11	523.73	
10	394.51	---4---
9	315.81	
8	256.88	
7	211.34	---3---
6	170.91	
5	135.00	
4	100.72	---2---
3	66.80	
2	33.23	---1---
1	0.00	=========Surface=========

Figure 3-6. Schematic comparison of RAMS3a and CAMx vertical grid system. This structure is consistent among all CAMx 32/16/4-km grids.

Results and Model Performance

OTAG has previously evaluated the performance of RAMS3a for the July 1995 episode (SAI, 1996). No specific analysis was performed for Texas, and results are described in general terms for the domain as a whole. While overall performance was judged to be good, some concerns were raised. First, the surface wind speeds were consistently under predicted for much of the eastern U.S., and wind directions were not well replicated in the central portion of the domain or near surface fronts or troughs. Also, daily maximum and minimum temperatures tended to be over predicted by 2-4°F, and a 2-hour lag in the diurnal temperature wave was noticed.

The focus of the performance evaluation for this study is on the accuracy of RAMS3a in East Texas.

Surface Temperatures

The performance of RAMS3a in simulating daily minimum and maximum temperatures for this episode was evaluated for East Texas, as well as for other major urban areas throughout Texas to understand model performance regionally. This comparison is presented in Table 3-3 for all cities evaluated.

In Longview, the ability of RAMS3a to replicate the daily minimum and maximum temperatures is remarkably good. Maximum temperatures agree within 1°F for the duration of the episode, while minimum temperatures are over predicted on most days by just 1-3 degrees. The same good performance exists for Dallas and for minimum temperatures in San Antonio. However, daily maximum temperatures in San Antonio are slightly over predicted by 2-3 degrees. For Victoria, the predicted diurnal temperature range is smaller than observed, with under predictions of maximum temperature by 6-7°F, and over predictions of minimum temperature by 3-4°F. This poor performance stems from two problems: (1) RAMS3a poorly resolving the Texas coastline with a 36-km grid spacing; and (2) interpolation of that data to the 32-km CAMx grid, which artificially spreads the influence of the coastal zone too far inland. These coastal impacts are not problematic for the East Texas area.

Table 3-3. Comparison of observed and RAMS3a predicted daily maximum/minimum temperatures (°F) in various cities in Texas during the July 1995 RSM episode.

	Longview		Dallas		San Antonio		Victoria	
	Obs	Pred	Obs	Pred	Obs	Pred	Obs	Pred
July 7	96/71	96/72	96/71	96/72	89/74	92/72	91/76	87/78
July 8	98/72	98/75	98/74	97/72	91/74	93/73	93/73	87/77
July 9	98/76	98/74	99/75	99/72	91/69	94/71	94/73	88/76
July 10	98/76	99/76	102/75	102/74	94/73	98/73	95/73	89/76
July 11	99/75	100/79	103/75	103/75	95/70	98/73	97/71	89/76
July 12	98/76	98/79	102/78	101/78	95/72	97/75	95/71	88/76

Surface Wind Speeds

A plot of observed and modeled surface wind speeds at GGGC is provided in Figure 3-7. In general, observed wind speeds remain below 2.5 m/s for most of the period, except for some higher speeds occurring on the afternoons of July 9, 10, and 12. RAMS3a performs rather well in replicating the diurnal variations in speed each day, yet tends to over predict the lowest calm winds during the night and early morning hours. This is typical of meteorological models, and this feature was seen in the SAIMM fields as well. The overall good performance in wind speed is shown in terms of a scatter diagram in Figure 3-8; when winds below 0.5 m/s are removed (Figure 3-9), the slope improves toward 1:1 yet the correlation remains about the same, which suggests no significant change in the scatter (under/over prediction tendency). This performance is remarkable considering the coarse resolution of the simulation in this area and the fact that Texas was not a focal point of the OTAG modeling.

Surface Wind Directions

A comparison of observed and measured wind directions at GGGC are provided in Figure 3-10 for hours in which wind speed was above 0.5 m/s. RAMS3a performs well in tracking the directional changes day-to-day, with the change in westerly winds on July 8, 9, and 10 to northwesterly on July 11 and eventually to easterly on July 12. RAMS3a also reflects the prominent variations that occurred within each day, but generally these wind shifts were not modeled to be as large as observed. The typical error is about 30 degrees for these 12-hourly shifts and the largest error is associated with the lowest wind speeds. Certainly some of this error can be attributed to the coarse resolution. Wind direction on July 12 is not modeled particularly well, with error of up to 90 degrees in the afternoon (modeled southeasterly vs. observed northeasterly). This occurs under light but organized flow conditions. A scatterplot showing the correlation of measurements and predictions (Figure 3-11) indicates good performance overall in replicating the two wind direction regimes (westerly and easterly).

Boundary Layer Depths

Figure 3-12 shows a time series of approximated CAMx PBL depths diagnosed from the RAMS3a inputs for three key days of interest. The consistency in the daily evolution of vertical mixing is noteworthy, and suggests that RAMS3a is predicting a consistent meteorological regime day after day. The only obvious variation among these days is the slightly slower development of boundary layer growth on the morning of July 11.

Peak mixing depths are higher than diagnosed in the SAIMM fields reported earlier (1800 m vs. 1400 m). However, this may be an artifact of the relatively coarse layer structure in the June 1995 RSM that spans 1400-2100 m, so we do not attach much significance to this difference. The key difference between RAMS3a- and SAIMM-derived mixing depths is the slower growth rates each morning in RAMS3a. By 1100 CST each day, SAIMM mixing heights have reached the maximum diagnosed level, whereas the RAMS3a mixing heights only extend to 700 m. As described in Section 5 of this report, this will play a key role in air quality modeling performance issues for the July 1995 RSM. Another difference is the fact that SAIMM mixing heights drop quickly after about 1700 CST (also noted by TNRCC), but RAMS3a mixing heights stay high for another two hours. The RAMS3a performance in this regard is more consistent with observed characteristics of boundary layer turbulence. The nighttime mixing depths in Figure 3-12 are much lower than for the SAIMM CAMx inputs since no artificial Kv increases were applied to these fields.

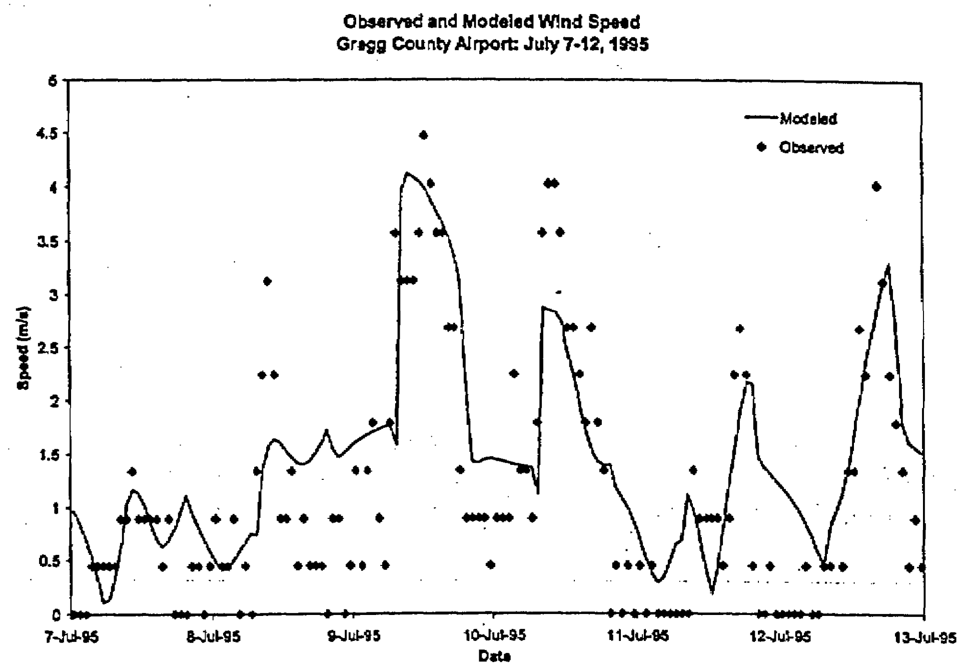


Figure 3-7. Time series of RAMS3a-modeled and observed surface wind speeds at the Gregg County Airport on July 7-12, 1995.

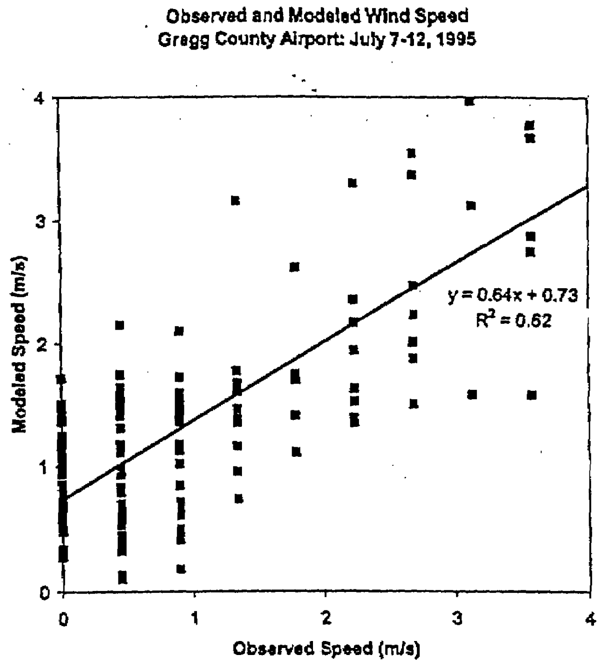


Figure 3-8. Scatter plot of RAMS3a-modeled and observed surface wind speeds at the Gregg County Airport on July 7-12, 1995.

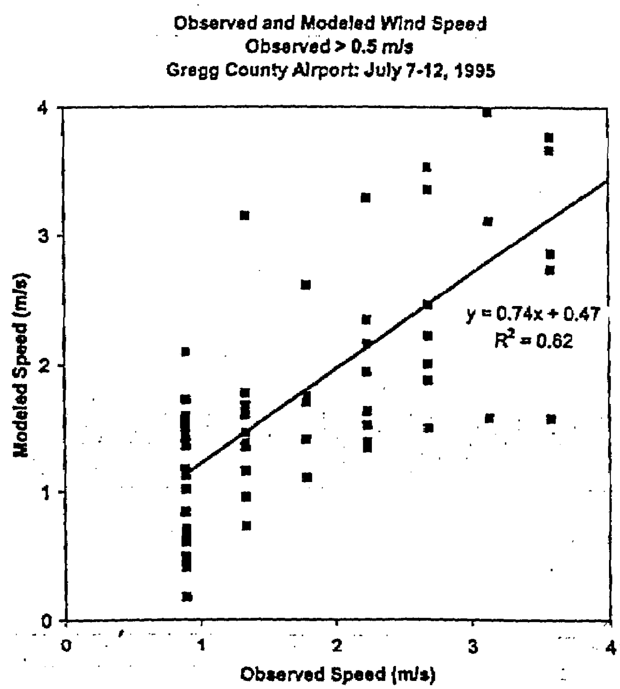


Figure 3-9. Scatter plot of RAMS3a-modeled and observed surface wind speeds at the Gregg County Airport on July 7-12, 1995.

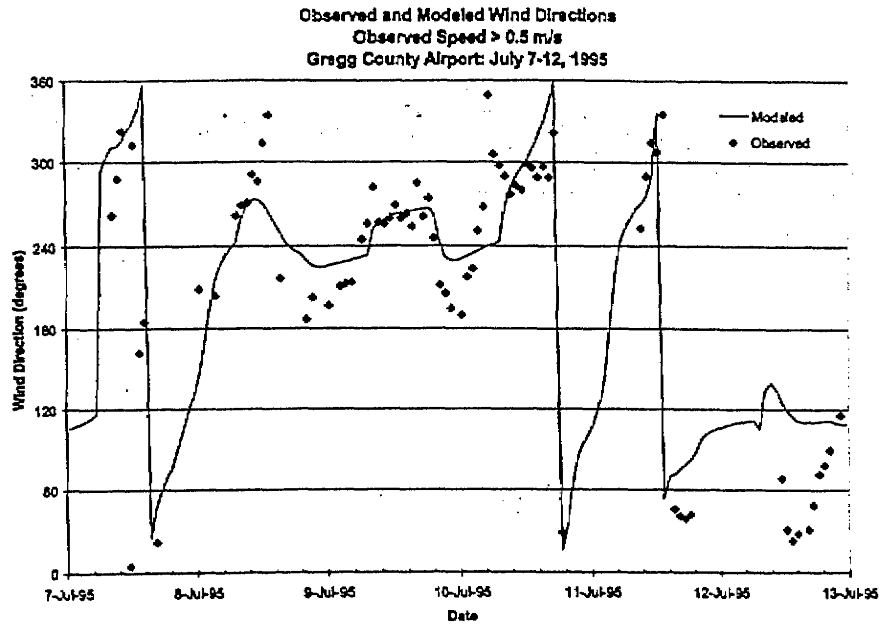


Figure 3-10. Time series of RAMS3a-modeled and observed surface wind direction at the Gregg County Airport on July 7-12, 1995 for observed winds speeds greater than 0.5 m/s.

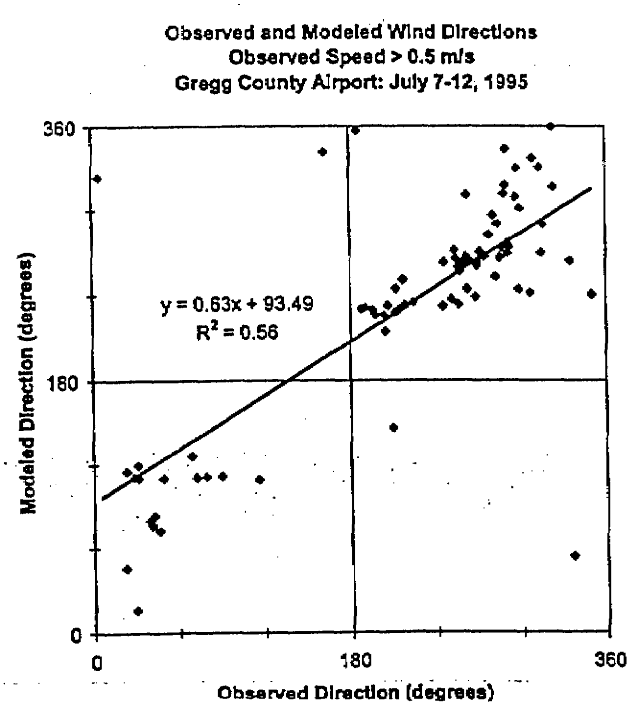


Figure 3-11. Scatter plot of RAMS3a-modeled and observed surface wind directions at the Gregg County Airport on July 7-12, 1995 for observed winds speeds greater than 0.5 m/s.

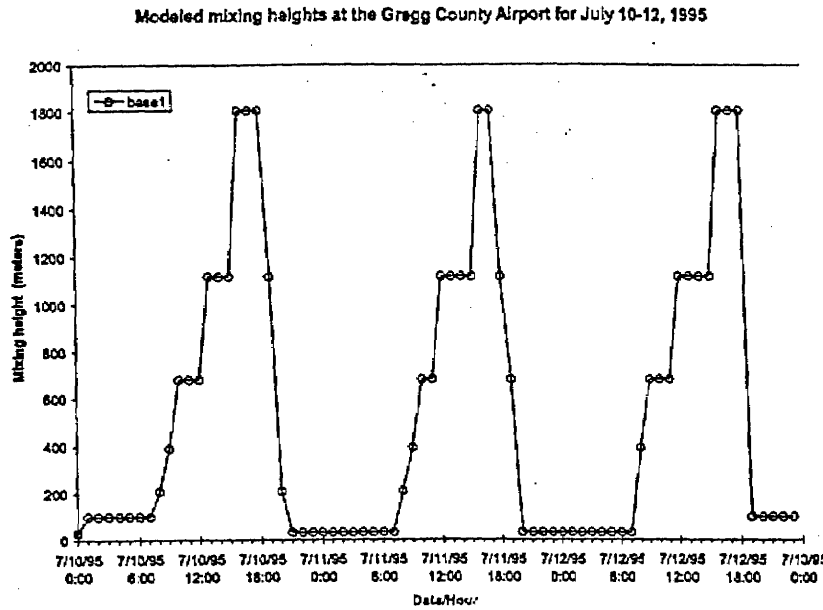


Figure 3-12. Approximated PBL depth at the Gregg County Airport on July 10-12, 1995, derived from CAMx input fields of vertical diffusion coefficient.

AUGUST 14-18, 1997 USM

Ozone at Longview exceeded the 1-hour standard on just one day during this episode (August 16), but 8-hour ozone was high on August 16-18. Meteorological patterns during this period were controlled by the presence of a very expansive high pressure ridge aloft centered over the Rocky Mountains that extended well into the eastern U.S. While quite broad, the ridge was characterized by a relatively low amplitude, which allowed small weak disturbances to propagate through the central U.S. These caused some spotty thunderstorm activity associated with very weak surface troughs imbedded within the otherwise high-pressure weak-gradient surface conditions that dominated the south-central U.S. Winds aloft remained very weak from the north and northeast, while surface winds were stagnant and varied considerably with the movement of the weak systems through the area. While most days were characterized by little cloudiness, there were occasions during this episode when high cloudiness and small-scale precipitation features were present in the area. Daily maximum temperatures remained steady at 95°F over July 16-18. So while the meteorology in East Texas could be considered quiescent and stable, small transient systems did impose their influence and resulted in more complex conditions than had been seen in the other modeling episodes.

To add to the complexity, a small hurricane ("Danny") formed late on July 16 just off the Louisiana gulf coast and slowly skirted eastward into Mobile, Alabama by July 19. It's size, as determined by its surface pressure perturbation, remained only 200-250 km in diameter, but it influenced regional wind and moisture patterns in eastern Texas and Louisiana for the period of interest.

Meteorological Modeling Methodology

No meteorological modeling database was available for this area and period for the purposes of a photochemical modeling study. Therefore, the Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) fifth-generation mesoscale model version 2 (MM5v2) was chosen to develop appropriate meteorological inputs for CAMx. Like RAMS, the MM5 is a non-hydrostatic nested-grid model that contains options for FDDA, soil thermodynamic models, and treatments of cloud micro-physics, cumulus convection, and precipitation processes. It also offers several options for boundary layer (mixing) parameterizations. Unlike RAMS, the MM5 vertical coordinate is formulated in terms of atmospheric pressure, rather than physical height. Also, for mid-latitude applications, the MM5 grid system is defined on a Lambert conformal projection.

Since the MM5 applications for this project represented original work, the model was uniquely configured to address the needs of the July 1997 USM. A key factor in this was the definition and placement of the Lambert conformal grid projection so that it would match the UTM CAMx grid as closely as possible. CAMx can operate on exactly the same Lambert grid specified for MM5, but in this case the CAMx domain was defined in terms of the TNRCC UTM grid system for consistency with the other episodes modeled in this study and with historical modeling efforts in Texas. The MM5 domain was defined as a two-grid system comprising an outer domain at 36-km resolution covering most of the U.S. and Mexico, and a 12-km nested grid covering the south-central U.S. Figure 3-13 displays the coverage of this domain. Careful consideration was given in specifying the MM5 Lambert projection parameters so that the 12-km fine grid would overlay the CAMx 4-km UTM grid with sufficient precision to remove the need for extraneous interpolation procedures when mapping meteorological variables to CAMx inputs. The resulting MM5 grid agrees with the CAMx grid to within 2 km at the corners of the USM domain.

Given the weather features present in the central U.S. during this episode, the MM5 was configured to treat cloud physics and rainfall processes. Ignoring these effects would have resulted in the inability of MM5 to replicate hurricane Danny and thunderstorm activity in the central U.S., as well as the their dynamic influences on wind flows and temperature structures in the East Texas area. FDDA was also employed. The source of analysis data supplied to MM5 was provided from Eta model products generated by the National Center for Environmental Prediction (NCEP) and distributed by NCAR. The Eta is an operational forecasting model used to provide day-to-day weather forecasts for the nation. This model is run every 12 hours; before each forecast, Eta is run in an initialization (or "spin-up") mode to simulate the previous 12 hours while ingesting various observational data into its own FDDA system. Observational data used include surface and rawindonde observations, ship, buoy, and aircraft measurements, Doppler radar data, and satellite data. The Eta initialization output fields, provided every three hours were used as input to the MM5 FDDA system for July 14-17. For July 18, the Eta fields were not available, so NCEP gridded global analysis fields were used instead.

The translation of MM5 output fields to CAMx inputs was performed using the MM5CAMx processor. This step was performed in a relatively straightforward manner due to the fact that only a single 4-km CAMx grid was utilized for the USM and that the MM5 12-km grid aligned with the CAMx domain quite closely. Therefore, the only interpolation that was necessary was to the finer air quality resolution. Table 3-4 presents the gridded meteorological parameters required by CAMx, and the MM5 variables from which they are derived. In the table, sigma-p is the dimensionless normalized vertical pressure coordinate, p* is the column pressure depth, and p_{top} is the pressure at model top (100 mb). As a way to limit the degree of error associated with vertical aggregation of meteorological data to the coarser CAMx layer structure, we defined CAMx layer interface heights to match a subset of MM5 layer interfaces instead of specifying a constant height grid. These heights expand and contract spatially as a function of underlying terrain heights and the initial atmospheric pressure distribution (see Figure 3-14 for an illustration of the vertical height grid at sea level assuming a U.S. Standard Atmosphere).

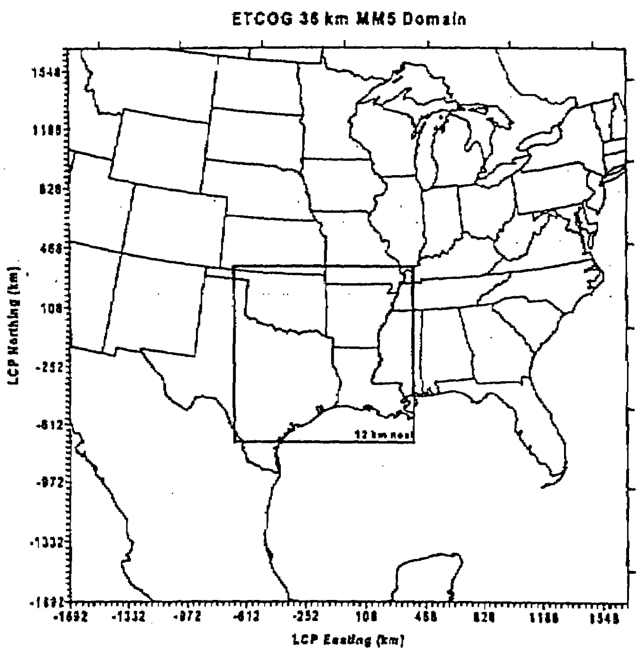


Figure 3-13. Location and extent of the MM5 nested grid domain, indicating the position of the 12-km nest within the outer 36-km grid.

```
  MM5 Layer Interface Heights
      k          height            CAMx Layer Interface Heights
  =========================== ===========================
      19        3615.47                    --12---
      18        3105.15
      17        2640.09                    --11---
      16        2196.12
      15        1825.61                    --10---
      14        1521.13
      13        1277.13                    ---9---
      12        1072.57
      11         905.20                    ---8---
      10         773.24
       9         642.97                    ---7---
       8         514.33
       7         387.28                    ---6---
       6         261.77                    ---5---
       5         170.94                    ---4---
       4         101.61                    ---3---
       3          51.07                    ---2---
       2          18.26                    ---1---
       1           0.00          =========Surface=========
                                 /////////////////////////
```

Figure 3-14. Schematic comparison of MM5 and CAMx vertical grid system.

Table 3-4. Relationship between MM5 and CAMx gridded meteorological parameters.

CAMx variable	RAMS variable(s)
Layer interface height (m)	Sigma-p coordinate, p* (kpa), p_{top} (mb)
u-component (east/west) wind (m/s)	u-component wind (m/s)
v-component (north/south) wind (m/s)	v-component wind (m/s)
Temperature (K)	Temperature (K)
Water Vapor (ppm) (coarse grid only)	Water vapor mixing ratio (kg/kg)
Pressure (mb)	Pressure perturbation (Pa), p* (kPa), p_{top} (mb), sigma-p coordinate
Vertical Diffusivity (m^2/s)	Temperature (K), winds (m/s), pressure (mb), water vapor (kg/kg), PBL depth (m)
Cloud Cover (coarse grid only)	Water vapor (kg/kg), cloud water (kg/kg), temperature (K), pressure (mb)
Rainfall Rate (in/hr) (coarse grid only)	Cumulative convective + non-convective rainfall (cm)

Most three-dimensional prognostic variables (winds, temperature, pressure, etc.) directly output by MM5 are coupled to the p* variable, and must be de-coupled before they are used in calculations and before they are written to CAMx-ready files. However, MM5CAMx maintains this coupling through the horizontal interpolation and vertical aggregation of winds, temperature, moisture, and pressure. This allows p* to act as a natural mass-weighting factor. No rotation of winds were necessary between the MM5 and CAMx grids.

These MM5 runs did not supply fields of vertical diffusion coefficients or TKE since a boundary layer parameterization was chosen for MM5 that is not based upon K-theory. However, the scheme chosen did supply fields of PBL depth. Initially, the plan was to apply a first-order diagnostic approach in MM5CAMx to develop vertical diffusivity fields from the hydrodynamic variables, as was done for RAMS3a output. However, none of the methodologies tested yielded acceptable Kv fields because they resulted in effective PBL depths that were far lower than produced by MM5 in cloud-free conditions. Thus, the analytic approach of O'Brien (1970) was adopted for MM5CAMx. This approach specifies a vertical profile of Kv within a given PBL depth, which in this case was taken directly from MM5 output for each grid column. This allowed the effective mixing depths in CAMx to match those produced by MM5.

Inspection of the MM5 PBL fields raised other concerns, however. It was found that midday mixing depths under areas of significant cloud cover were very shallow (within a few 100 meters of the ground), presumably a result of cloud shading of the surface. However, the bulk of cloudiness in the simulation was of the convective type, which by definition is largely a result of boundary layer mixing and buoyant rise (apparently, there is not a strong linkage between the separate boundary layer and the cloud models in MM5). In reality, the boundary layer is often quite turbulently active, so an approach was adopted in MM5CAMx to raise the deficient MM5 mixing depths under clouds to more appropriate levels. A mean PBL depth over the entire grid was calculated each hour from mixing depths in cloud-free columns and the cloud base heights in cloudy columns. Then, the domain-mean PBL depth was assigned to all grid columns in which the MM5 PBL depth was less than half the domain-mean PBL depth. The O'Brien (1970) analytic Kv methodology was then applied to the redefined grid columns.

CAMx cloud fields were diagnosed from the MM5 resolved cloud water fields, as well as from a relative humidity threshold technique as suggested by Geleyn (1981) and utilized by Lin et al (1994) and Emery et al (1996). The MM5 cloud water fields were used to diagnose the extent of resolvable clouds (i.e., 100% cloud cover) in each CAMx cell. MM5CAMx included the Geleyn approach to determine the extent of sub-grid scale cloudiness (<100% coverage). Since cloud water was not available from MM5 output for unresolved cloudiness, default values of cloud water were specified depending on layer altitude.

Results and Model Performance

The MM5 model performance evaluation was split into two areas: a qualitative analysis of the model in replicating weather features on the large scale, and a statistical analysis of winds, temperatures, and mixing depths locally in East Texas similar to the previous descriptions for SAIMM and RAMS3a. The regional qualitative analysis focused on a comparison between MM5 wind and temperature fields and daily weather maps prepared by the NWS. The daily maps provide surface and 500 mb charts at 1200 UTC (0600 CST), as well as daily maximum/minimum temperatures and 24-hour precipitation totals for major cities across the U.S. The local analysis of meteorological parameters is performed for the GGGC site; similar analyses were conducted for Tyler as well, with very similar results. Therefore, only the performance at GGGC is presented here.

Regional Analysis

July 14, 1200 UTC: Three surface features were prevalent on this morning: a 1020 mb high centered over Colorado, a 1018 mb high over the southeast U.S., and a weak cold front extending from a low over Lake Superior (1005 mb) through Missouri and into New Mexico, bifurcating the two high pressure areas. MM5 reproduced all of these features rather well, except that the Colorado high was centered over Wyoming. Predicted surface winds were generally 5 m/s or less throughout the region and just slightly stronger near the cold front, where some convergence was simulated; this convergence lined up nicely with the location of the observed front. MM5 replicated the warmest temperatures east of the cold front. Temperatures on the 36-km domain were predicted well, but temperatures on the 12-km nest were a little high in predicting low 80's in Arkansas, Oklahoma, and northeast Texas when observations were in the mid 70's. In addition, a predicted cold pocket of air in central Texas (66°F) was too low. At 500 mb, a 5880 m high extended across the entire southern half of the U.S., which the model simulated well. A predicted weak trough over the Dakotas and Minnesota and a strong ridge to its east were in good agreement with the observations.

July 15, 1200 UTC: A 1020 mb high existed over southwest Utah and a weak 1016 mb low was located in southeast Colorado. Two weakening fronts trailed down the eastern quarter of the country while the southern states were nearly isobaric under weak high pressure. The most notable contrast between MM5 and the observations took place in the mountain states, where MM5 predicted a non-existent 1025 mb high over central Colorado and also predicted the low over southeast Colorado to be 2 mb too deep, generating a very strong pressure gradient in this area. Elsewhere, MM5 pressure gradients were weak and surface winds were mainly 5 m/s or less. Wind directions replicated the observed patterns. MM5 predicted temperatures reasonably well, correctly establishing the highest temperatures in northeast Texas and Arkansas. However, temperatures in the 12-km domain at this time were too high (84°F predicted vs. upper 70's observed). Cool temperatures were predicted to the west of the Great Lakes in agreement with observations, but the minimum near Lake Superior was too low. Further to the west, the northern plains were simulated to be too warm by about 10 degrees. At 500 mb, MM5 predicted a 5950 m high over New Mexico, which agreed well with the 5940 m high analyzed around the Four Corners. All the other height contours were in close agreement with measurements except for an analyzed dip in the 5880 m contour into the southeast U.S.

July 16, 1997, 1200 UTC: MM5 over predicted the high pressure centered over Colorado by 10 mb. In addition, the weak surface troughs to its north and east were under predicted, generating much stronger pressure gradients than observed. Simulated extensive high pressure covered most of the region to the east, agreeing with observations. Both model and observations showed a low pressure trough along in the eastern seaboard. Winds were generally light across the region. MM5 generally predicted winds near 5 m/s in the 36-km grid while observations were calm; however, wind speeds were lower in this area in the 12-km grid. MM5 did not replicate any convergence near a surface trough in the Dakotas. As a result, southwest winds were simulated instead of southeast. MM5 predicted surface temperatures quite well except perhaps in central Colorado. There, a minimum of 49°F was simulated while the surrounding stations were in the 60's. MM5 adequately represented the dominance of high pressure across the country at 500mb, including a local peak at or greater than 5940 m near the Four Corners. In addition, the predicted 5880 m contour closely mimicked the observed pattern.

July 17, 1997, 1200 UTC: Again, MM5 over predicted the magnitude of high pressure (1020 mb) in central Colorado by about 10 mb; weather maps showed a high centered just south of the state at 1016 mb. A predicted low over southern Montana was too far east and 4 mb too deep. A 1018 mb high simulated in western North Carolina agreed well with the magnitude of an observed high but was positioned slightly too far east. Otherwise, the pressure patterns in the remainder of the 36-km domain was very representative. Tropical Storm Danny was simulated to be much weaker in both the pressure and wind magnitude. Danny in MM5 did not influence wind directions in Louisiana, unlike the observations at New Orleans and Lake Charles. Simulated winds were too strong over Nebraska and Kansas, possibly due to a stronger disturbance entering the plain states than what actually occurred. In addition, MM5 winds in eastern Texas, Louisiana, Mississippi, and Arkansas were light (5 m/s) but too organized relative to the wide occurrence of calm and foggy conditions reported at this time. In the 12-km grid these winds eased a bit, particularly in eastern Texas. Based on simulated convergence patterns in the wind field, a stationary front across the northern plains appeared to be too far to the south. Temperatures simulated by MM5 were reasonable overall. One exception was the warmth over the northern plains, particularly Minnesota (upper 70's simulated vs. upper 60's observed). The 500 mb height patterns continued to agree quite well with measurements. Again, the 5880 m contour extending into South Dakota and then plunging down to Florida mimicked the weather map.

July 18, 1997 1200 UTC: Once again, the pressure pattern in central Colorado was predicted to be about 10 mb too high. A vigorous low pressure system observed in the Dakotas was well simulated in terms of magnitude, but was placed too far to the south in MM5. A 1007 mb low in northern Texas and New Mexico was correctly simulated. The isobars in the remainder of the domain matched the observations well, except that Hurricane Danny was not simulated to be as far northeast as observed at this time. The simulated surface wind field was very reasonable, and most winds were 5 m/s or less. Wind directions agreed with the observations except for those locations where the low pressure centers were not located properly. Temperatures appeared fine overall except in central Colorado, where they were too low. MM5 continued to perform well for the 500 mb height fields. Both the model and the measurements placed the ridge axis in the center of the country with a local peak over Nebraska. The predicted 5880 m contour followed the analyzed contour well.

Synopsis: The MM5 simulation for this period performed well in replicating the observed major weather features that evolved over the eastern two-thirds of the U.S. Three major performance issues were identified, and were consistently present throughout the simulation:

- Pressure and temperature performance in Colorado was sub-par. This was likely due to the combination of complex and high terrain very near the western boundary of the 36-km domain and error entering in through the assimilation of Eta model analyses in that area. The potential for the development of numerical error under such circumstances is very high, and these can propagate far into the domain during such long simulations. The propagation of such error was not obvious in this run, but the simulation of resolved disturbances (lows and troughs, and associated thunderstorm activity) in the lee of the Rocky Mountains and into Texas could have been effected. We assume that the FDDA procedures kept most of the error east of Colorado in check.
- Morning minimum temperatures seemed to be over predicted for a wide area of the domain, particularly in the central plains states. The reasons for this are unknown, but likely causes include over predictions in nighttime humidity, which traps heat near the surface; overly high near-surface turbulence, which transfers heat from aloft; and an inaccurate soil thermodynamics model, either through deficiencies in the model, inappropriate soil characteristics for the landuse supplied to MM5, or inaccurate landuse inputs themselves.
- The development and propagation of Hurricane Danny was not predicted well. This could have ramifications for the accuracy of flow, temperature, and precipitation features in East Texas.

Surface Temperatures

Figure 3-15 presents a time-series display of measured and predicted surface temperature at GGGC for the duration of the episode. Daily peak temperatures reached about 93°F (307 K) each day, while minimum temperatures slowly increased over the period from 74°F (296.5 K) to 77°F (298 K). Note that the presence of clouds is apparent at GGGC on July 15, with the sudden cooling after about 1000 CST. MM5 performance in replicating the observed trends is mixed. MM5 simulates the warming trend each morning and the daily maximum temperature fairly well. However, MM5 does poorly in simulating afternoon and evening cooling, with overly rapid cooling on some days and insufficient cooling on others. Another obvious feature is the consistent over predictions of daily minimum temperature. This is consistent with the regional results described above. Since most of the over predictions occur at night or very early in the morning, and the late-morning temperature increases are well replicated, it is not obvious how this error would affect the ozone simulations, but we believe that the effects would be rather small. One consequence of the observed differences between observed and predicted temperatures was to decide that biogenic emissions for the episode should be generated from hourly observations at Longview and Tyler. A strange temperature feature is the sudden warming around midnight on July 18; it is believed that this may be due to the presence of fairly low thick clouds that have inhibited cooling of the surface and increased downward warming. This feature is also associated with a shift in wind direction from northeasterly to southeasterly, suggesting the intrusion of a warmer air parcel.

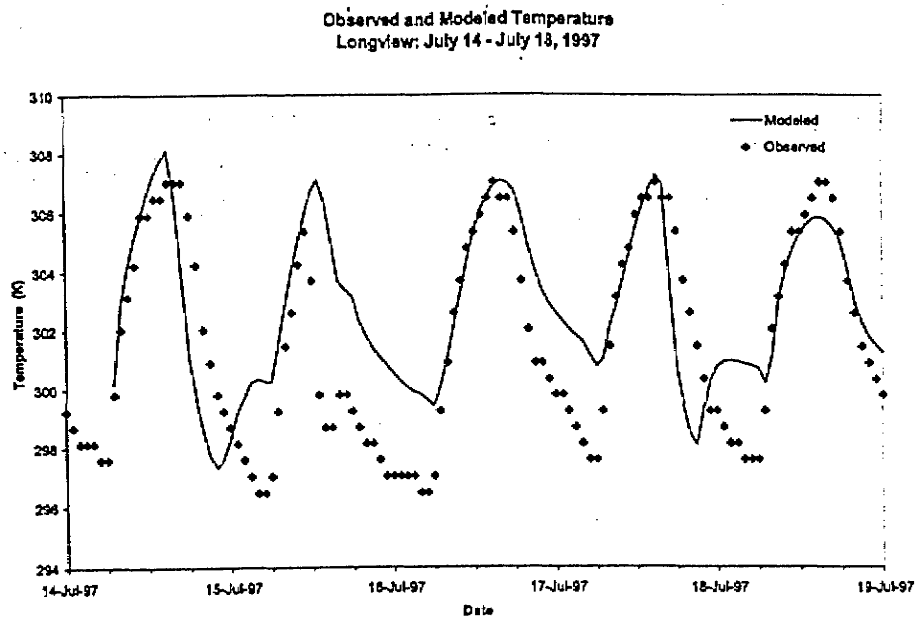


Figure 3-15. Time series of MM5-modeled and observed surface temperatures at the Gregg County Airport on July 14-18, 1997.

Surface Wind Speeds

A plot comparing surface wind speeds is provided in Figure 3-16. The observations display a high degree of variation of most days, but overall the speeds remain less than 2 m/s for the duration of the episode. The MM5 performance in replicating the noisy measurements is troubling; MM5 also simulates a weak wind flow pattern with a high level of variability, but the predictions do not correlate with the observations. Scatter diagrams (not shown) indicate a near-zero correlation.

Some insight into this problem was gained by viewing animations of the MM5 wind and cloud fields on the 12-km grid. It was revealed that the MM5 produced some convective clouds each afternoon of the simulation, and these caused some ripple effects in the otherwise tranquil wind fields in East Texas due to cloud inflow/outflow patterns. This activity was presumably a result of the sporadic but weak transient disturbances that actually existed in the south-central U.S. on these days and even produced some precipitation. However, convective cloudiness at this scale is a highly random and complex phenomenon, and it is unrealistic to expect MM5 to replicate the exact timing, position, and strength of these convective cells, or the resulting outflow wind patterns. The fact that MM5 did produce convective cloudiness in the area suggests a correct model response to the larger conditions. Unfortunately, this increased level of randomness exerted a significant influence on the otherwise stagnant flow patterns.

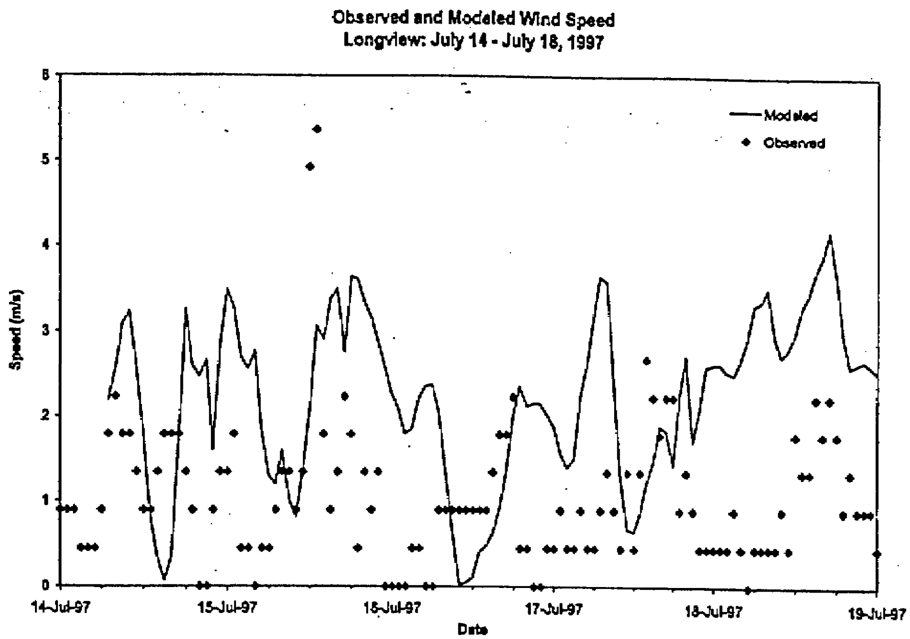


Figure 3-16. Time series of MM5-modeled and observed surface wind speeds at the Gregg County Airport on July 14-18, 1997.

Surface Wind Direction

With the high degree of variability in the slow wind speeds comes a commensurate level of variability in the wind directions, as seen in Figure 3-17. The wind direction observations indicate a diurnal pattern, in which near-calm winds pick up in the late morning out of the west, and then around noon they shift to northeasterly until sunset. With such weak synoptic forcing over East Texas, it is possible that this pattern is a result of a semi-diurnal tidal force of some kind, possibly due to afternoon convective activity in the area. The MM5 tends to mirror this pattern to some extent, but it does not replicate the full angular shift from westerly to northeasterly except on July 14. The MM5 tends to maintain the directions in the northeast and southeast quadrants for the remainder of the episode. This behavior of over-organizing the flow field is a known characteristic of most meteorological models. Performance on an hour-to-hour basis, therefore, does not appear to be particularly good. However, inspection of wind fields just above the surface (100-500 m) indicates much better behavior, with winds consistently from the east and south east in agreement with local rawinsonde observations.

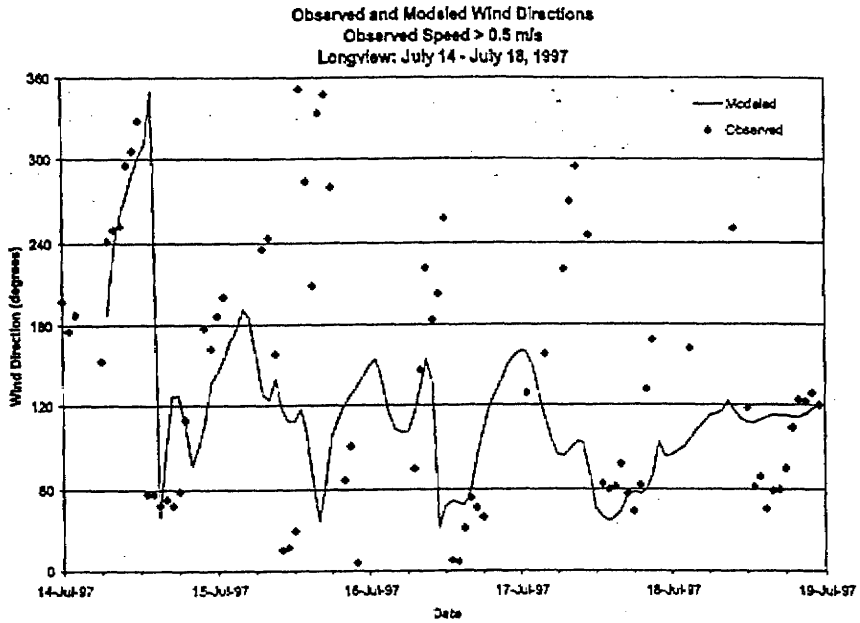


Figure 3-17. Time series of MM5-modeled and observed surface wind direction at the Gregg County Airport on July 14-18, 1997 for observed winds speeds greater than 0.5 m/s.

Boundary Layer Depths

Diagnosed boundary layer depths at GGGC are shown in Figure 3-18 for the last three days of the episode. Unlike the conditions for the two RSM inputs, the MM5-derived mixing depths show much more variability in growth/decay rates and maximum mixing depths. This may be partly a result of the influence of clouds on the mixing height that was present in the MM5 simulation, but absent in the SAIMM and RAMS3a modeling. Also obvious from these plots are the larger number of layers from which to resolve boundary layer growth. Overall, these results indicate that all three models (SAIMM, RAMS3a, and MM5) produce consistent PBL depths on the order of 1500-2000 m during stagnant summer days, and that the mixing decays rapidly into the evening to below 100 m.

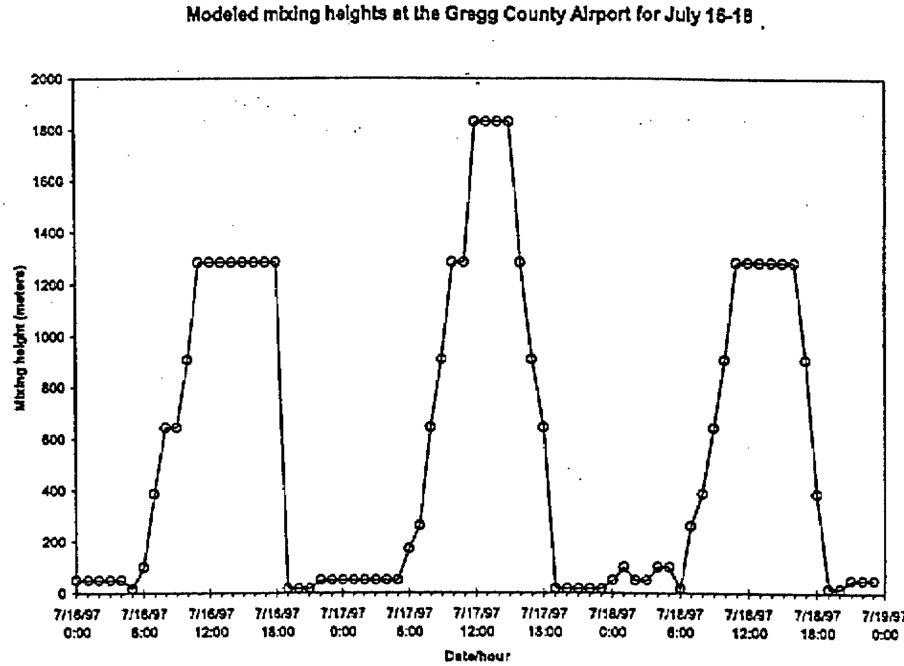


Figure 3-18. Approximated PBL depth at the Gregg County Airport on July 16-18, 1997, derived from CAMx input fields of vertical diffusion coefficient.

4. EMISSION INVENTORIES

OVERVIEW

This section of the report describes the emission inventory preparation for all three episodes.. Emission inventories were processed using version 2.0 of the Emissions Processing System (EPS2). The purpose of the emissions processing is to format the emission inventory for photochemical modeling using CAMx. Specifically, the emission inventory was allocated:

- Temporally – to account for seasonal, day of weak and hour of day variability
- Spatially – to reflect the geographic distributions of emissions
- Chemically – to account for the chemical composition of VOC and NOx emissions in terms of the Carbon Bond 4 (CB4) chemical mechanism used in CAMx.

Emissions for different major source groups (e.g., mobile, non-road mobile, area, point and biogenic) were processed separately and merged together at the end. This simplifies the processing and assists quality assurance (QA) and reporting tasks.

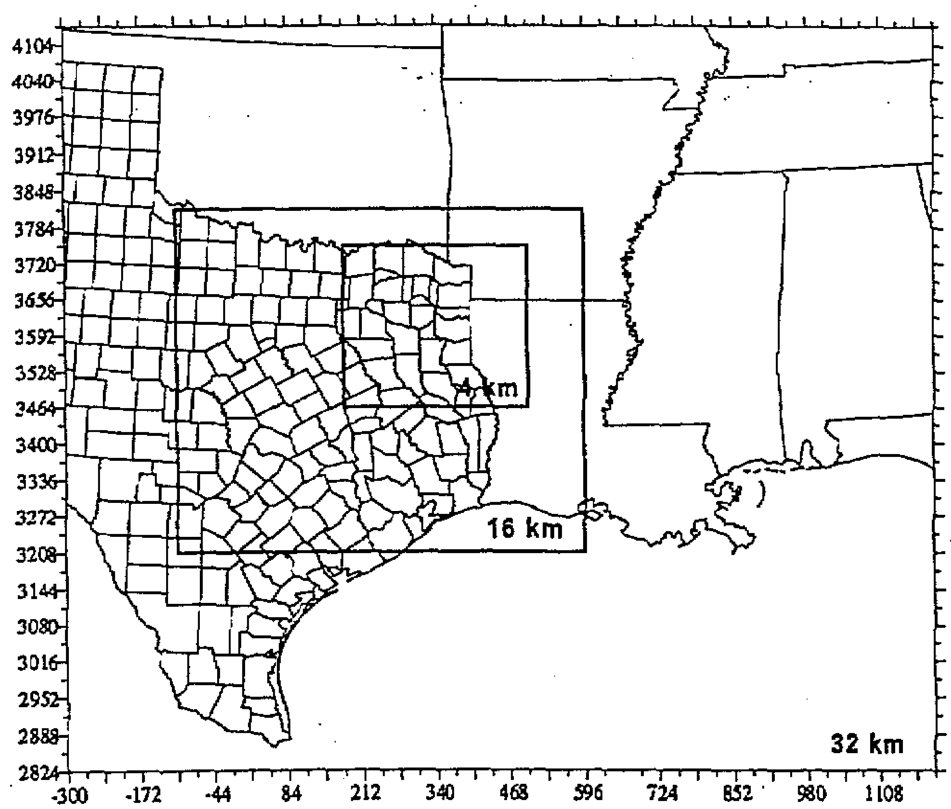
The regional scale episodes are being modeled in CAMx using a nested grid configuration with grid resolutions of 32, 16 and 4 km (Figure 4-1). In CAMx, emissions are separated between low level (surface and low level point) emissions and elevated point source emissions. For the low level emissions, a separate emission inventory is required for each grid nest, i.e., three inventories. For elevated point sources, a single emission inventory is prepared including all grid nests.

Two emissions modeling domains were used to generate the required CAMx ready inventories:

1. **Regional Emissions Grid.** The regional emissions grid has 94 x 82 cells at 16 km resolution and covers the full area shown in Figure 4-1. This emissions grid was used for the 16 km CAMx grid by "windowing out" emissions for CAMx 16 km nested grid. This emissions grid was also used to prepare emission inventories for the CAMx 32 km grid by *aggregating* four 16 km cells to one 32 km cell over the entire area.

2. **Tyler/Longview/Marshall Emissions 4 km Grid.** The TLM emissions grid has 80 x 72 cells at 4 km resolution and covers the same area as the CAMx 4 km nested grid as shown in Figure 4-2.

The emissions processing methodologies and results are described separately below for the Regional and TLM emissions grids.



UTM Zone 15 Coordinates

32 km Grid: 47 x 41 32 km cells from (-300, 2824) to (1204, 4136)

16 km Grid: 44 x 38 16 km cells from (-108, 3208) to (596, 3816)

4 km Grid: 80 x 72 4 km cells from (180,3464) to (500, 3752)

Figure 4-1. Regional Scale modeling domain with nested grid specifications.

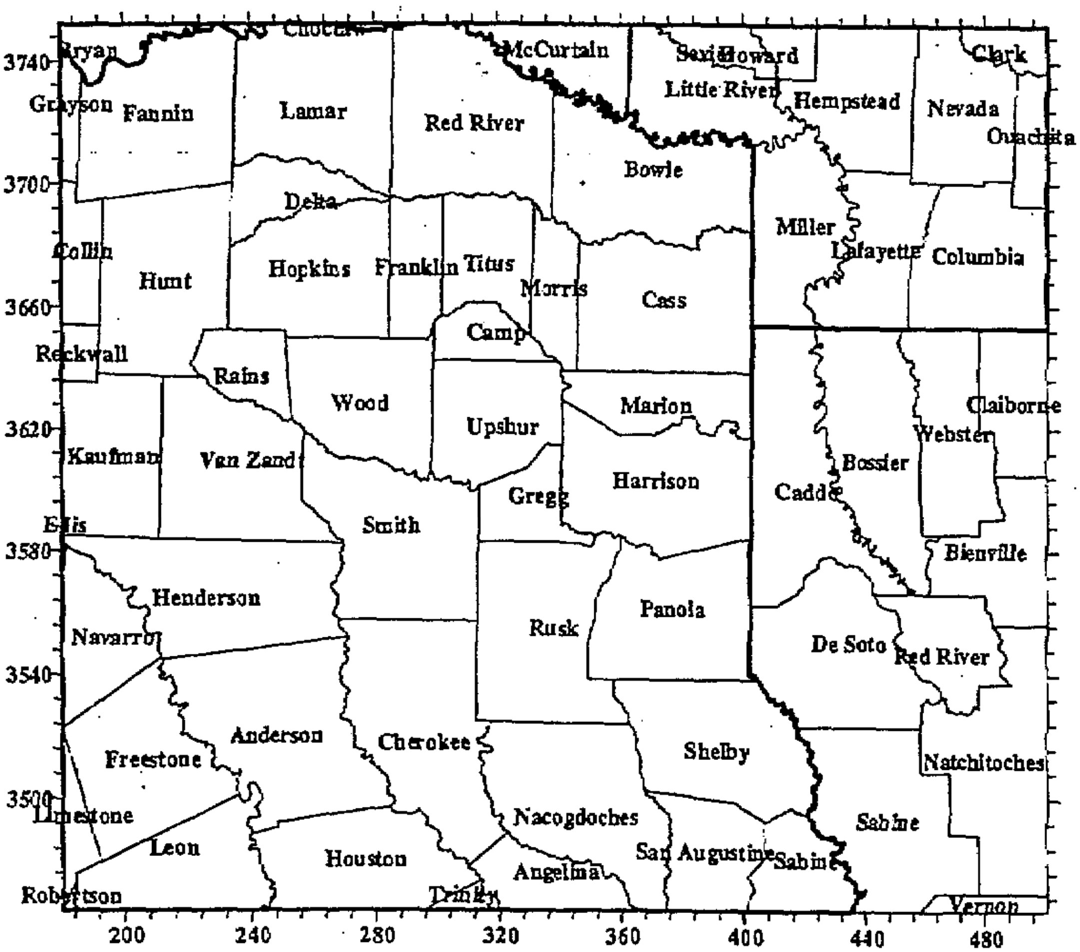


Figure 4-2. Tyler/Longview/Marshall (TLM) 4-km grid area.

BASE CASES 1 AND 2

Two base year emission inventories were developed in the process of this study, called Base Case 1 and 2, respectively. The only difference between these inventories was in the biogenic emissions. In describing the base year emissions preparation, the Base Case 1 inventories are described first. The Base Case 2 biogenic emission inventories are described separately at the end of the description of base year inventories.

REGIONAL EMISSIONS GRID

Area, Nonroad, and Point Sources

The most current TNRCC emissions inventory and EPS2 modeling setup were acquired from TNRCC for the regional emissions grid. This setup was used previously in the preparation of emission inventories for the Dallas/Fort Worth (DFW) regional modeling as described in TNRCC (1998). Gridded emissions are generated at 16 km resolution for the entire regional modeling domain. The 16 km emissions are then (1) aggregated to generate the 32 km domain emissions and (2)windowed out to generate the 16 km nested grid emissions.

The emission inventories received from TNRCC were processed through EPS2 using the TNRCC speciation, temporal allocation, and gridded spatial surrogate files. For area and nonroad sources each state was processed separately and the emissions were merged after gridding. Point sources were processed in five separate groups: Texas electric generating units (EGUs), other Texas point sources, Louisiana sources, offshore Gulf of Mexico sources, and all other sources.

June 1995

With the exception of the Texas EGUs, which contained some hourly day-specific emissions, separate emission inventories were prepared for a typical weekday and typical weekend day to be merged into the final model ready emissions as appropriate. The June 18-23, 1995 period was a Sunday through Friday. For the Texas EGUs, emissions were processed for each episode day. Since CAMx requires a single emission inventory for point sources in the regional and TLM emissions grids, further details on the processing of point source emissions are presented in Table 4-1 under the discussion of the TLM emissions grid.

Table 4-1. Elevated point source emissions for the regional domain for June 1995 (tons per day).

Major Source Category	6/18/95 Sunday			6/20/95 Tuesday		
	NOx	VOC	CO	NOx	VOC	CO
Texas Sources	2365.6	203.8	1173.5	2514.6	223.0	1182.2
Louisiana Sources	912.6	107.6	1673.1	914.6	110.4	1674.8
Offshore Sources	191.3	25.0	45.3	191.3	25.0	45.3
Other Regional Sources	3334.4	526.5	1593.7	3303.1	538.8	1584.6
Total Elevated Emissions	6803.9	862.9	4485.6	6923.6	897.2	4486.9

For quality assurance (QA), the EPS2 output message files were compared to those generated by the TNRCC to ensure an accurate transfer of data and processing.

July 1995

With the exception of the Texas EGUs, which contained some hourly day-specific emissions, separate emission inventories were prepared for a typical weekday, Saturday, and Sunday to be merged into the final model ready emissions as appropriate. The July 7-12, 1995 period was a Friday through Wednesday. For the Texas EGUs, emissions were processed for each episode day. Since CAMx requires a single emission inventory for point sources in the regional and TLM emissions grids, further details on the processing of point source emissions are presented below under the discussion of the TLM emissions grid.

Table 4-2. Elevated point source emissions for the regional domain for July 1995 (tons per day).

Major Source Category	7/7/95 Weekday			7/8/95 Saturday		
	NOx	VOC	CO	NOx	VOC	CO
Texas Sources	2455.5	222.6	1182.9	2263.2	208.4	1135.8
Louisiana Sources	914.6	110.4	1674.8	913.2	109.4	1673.9
Offshore Sources	191.3	25.0	45.3	191.3	25.0	45.3
Other Regional Sources	3303.1	538.8	1584.6	3341.1	542.0	1601.0
Total Elevated Emissions	6864.6	896.8	4487.5	6708.8	884.8	4455.9

For quality assurance (QA), the EPS2 output message files were compared to those generated by the TNRCC to ensure an accurate transfer of data and processing.

Mobile Sources

MOBILE5 was used to generate emission factors by roadway type and vehicle class for the regional mobile source inventory. There are 15 Texas counties (Brazoria, Chambers, Collin, Dallas, Denton, Fort Bend, Galveston , Harris, Hardin, Jefferson, Liberty, Montgomery, Orange, Tarrant, and Waller) in the modeling domain which have specific control programs in place due to their ozone non-attainment status. These counties have different inspection and maintenance (I/M), anti-tampering program (ATP), reformulated gasoline (RFG) status, model year distributions (MYRs) and operating mode fractions. The TNRCC provided (personal communication from Mr. Sam Wells) the MOBILE5 input files for these counties. The MOBILE5 inputs for all other counties required no special input parameters and default values were specified for all fleet characteristics including operating mode fractions. The gasoline volatility (RVP) was set at 8.3 psi as recommended by Mr. Wells.

Counties outside Texas that are in ozone non-attainment areas (Baton Rouge, Nashville, and Tulsa/Oklahoma City areas) where existing control programs are in place were treated similarly to all other ozone attainment counties because (1) these areas are far from East Texas and (2) because the only control programs in place are ATPs which do not alter emissions dramatically.

Mobile source emission factors depend strongly on temperature and so day specific temperatures were used in preparing mobile source emission inventories. Minimum and maximum daily temperatures were obtained from the National Climate Data Center (NCDC, 1999. The list of counties with specific control programs were examined individually and, where available, temperatures for these counties were used. For all other counties representative regional temperatures were used. The regional temperatures were obtained by placing minimum temperatures for numerous monitoring locations on a map (maximum on another) and then defining regions with similar temperatures. In this way the modeling domain was partitioned into seventeen separate temperature regions.

For counties in Texas, estimates of vehicle activity (vehicle miles traveled - VMT) by county and roadway type were provided by the TNRCC for 1996. In addition, total county VMT was provided for both 1995 and 1996 which was used to adjust the 1996 VMT resolved by roadway type to the 1995 modeling episode. For the non-Texas portions of the domain, 1995 VMT from the EPA National Emission Trends (NET) database were used (EPA, 1999).

Day specific mobile source emissions were calculated for each county using the VMT data and MOBILE5 emission factors. These data were further processed using EPS2 to allocate the emissions spatially (within each county), temporally and chemically. Emissions for VMT on roadway types classified as rural were spatially allocated to rural landuse areas. Emissions for VMT on roadway types classified as urban were spatially allocated based on population. Temporal allocation and chemical speciation followed the methodologies in the TNRCC emissions processing system for DFW.

For QA, the final gridded county totals were compared to the TNRCC mobile processing message files. In addition, mobile source emissions were plotted and the spatial/temporal distribution reviewed.

Surface Emission Totals

June 1995

The total surface anthropogenic emissions for the regional emissions grid are summarized in Table 4-3. The emission totals for area, non-road and point sources are for a typical weekend and weekday. The mobile source emissions are day specific because they depend upon temperature and the totals are for the day indicated.

Table 4-3. Total anthropogenic emissions by major source category for the regional emissions grid for June 1995 (tons per day).

Major Source Category	06/18/95 Sunday			6/20/95 Tuesday		
	NOx	VOC	CO	NOx	VOC	CO
Area & Nonroad Sources	3858	6242	22354	5506	7211	17571
Mobile Sources	3694	2325	19600	3694	2358	19800
Low Level Point Sources	367	1073	169	369	1112	171
Total	7919	9641	42122	9569	10681	37542

July 1995

The total anthropogenic emissions for the regional emissions grid are summarized in Table 4-4. The emission totals for area, non-road and point sources are for a weekday and Saturday. The mobile source emissions are day specific because they depend upon temperature and the totals are for the day indicated.

Table 4-4 Total anthropogenic emissions by major source category for the regional emissions grid for July 1995 (tons per day).

Major Source Category	07/07/95 Weekday			07/08/95 Saturday		
	NOx	VOC	CO	NOx	VOC	CO
Area & Nonroad Sources	5456	7105	17312	4677	6907	22960
Mobile Sources	3626	2454	20200	2719	1877	15300
Low Level Point Sources	365	1098	169	364	1082	168
Total	9448	10656	37681	7760	9867	38428

Biogenic Emissions for Base Case 1

Biogenic emissions are strongly temperature dependent and so day specific biogenic emissions were prepared using hourly gridded temperatures. For the regional grid, biogenic emissions were estimated using the latest version of EPA's BEIS2 biogenic processor, as described in TNRCC (1998) and ENVIRON (1999). This system uses the BEIS2 default landuse/landcover (LULC) data (the BELD database) gridded at a spatial resolution of 16-km.

There are two approaches to obtaining the hourly, gridded temperature data needed to prepare the biogenic emission inventory: (1) interpolation of observed temperature data recorded at monitoring sites in the regional domain, and (2) use of the surface temperature data estimated by the prognostic meteorological model. There are tradeoffs with either approach. Surface temperature observations tend to be clustered in urban/suburban environments which are not representative of the rural/forested environments where most of the biogenic emissions occur. The spatial interpolation of these observations does not account for factors that influence surface temperature (e.g., landuse, terrain elevation) and may tend to overestimate regional temperatures. On the other hand, prognostic meteorological model temperatures also may exhibit inaccuracies or biases related to the limitations of the meteorological model.

June 1995

The ability of the meteorological model (SAIMM) run by the TNRCC for the DFW modeling to replicate observed maximum temperatures at several locations (Shreveport, Dallas, Victoria and Austin) was evaluated. The maximum temperatures are most important for biogenic emissions estimation because the biogenic emissions are highest when the temperatures are highest in the daytime. SAIMM tended to underpredict maximum temperatures by 2 to 3 °C. This bias in SAIMM has been noted previously by the TNRCC (1998). The approach adopted here was to adjust the SAIMM temperatures 2 °C higher for the purposes of biogenic emissions estimation only. This preserves the spatial distribution of temperatures predicted by SAIMM while compensating for the model bias. This approach causes the surface temperatures to be overestimated at night, but this is not an important limitation because biogenic emissions at night are much lower than during the day because isoprene emissions only occur in sunlight.

Table 4-5. Base Case 1 biogenic emissions for the regional emissions grid for June 1995 (tons per day).

	VOC	NOx
June 18	73169	1651
June 19	76379	1696
June 20	74628	1692
June 21	81148	1731
June 22	85408	1758
June 23	89373	1780

July 1995

The ability of the meteorological model (RAMS) run for the OTAG modeling to replicate observed maximum temperatures at several locations (Longview, Dallas, Victoria and San Antonio) was evaluated. The maximum temperatures are most important for biogenic emissions estimation because the biogenic emissions are highest when the temperatures are highest in the daytime. RAMS performed very well in predicting maximum temperatures at Dallas and Longview: agreement was generally within 1°C with no bias toward over or underprediction. Thus, the RAMS predicted temperature fields were used directly to estimate biogenic emissions.

Table 4-6. Base Case 1 biogenic emissions for the regional emissions grid for July 1995 (tons per day).

	VOC	NOx
July 7	93126	1805
July 8	96373	1866
July 9	99120	1923
July 10	102887	1988
July 11	113444	2061
July 12	119375	2077

TYLER/LONGVIEW/MARSHALL 4 KM EMISSIONS GRID

Area & Nonroad Sources

The 1996 emissions inventory developed by Pollution Solutions (1998) was used for the Tyler/Longview/Marshall (TLM) domain. In addition to the 1996 inventory, Pollution Solutions (PS) provided emissions backcast to 1995. The backcasting was based on growth factors by emissions category provided by the TNRCC. The emissions data were provided as a spreadsheet which was reformatted for EPS2 processing. The area and nonroad source emission inventory developed by PS covers five counties; Gregg, Harrison, Rusk, Smith, and

Upshur. The TNRCC emission inventory was used for the other counties in the 4 km TLM domain.

The county level area and nonroad emissions were spatially allocated within each county using gridded spatial surrogates at 4 km resolution. The gridded surrogates were developed for this study using ARC/Info GIS from 1990 US census data, USGS landuse data, and county area. The TNRCC cross reference from source category code to spatial surrogate code was used with some minor changes. Oil production was mapped to rural (i.e., non-urban) land instead of range land because we found that some of the counties with large oil production emissions contained no range land and so emissions were being lost in the gridding phase of processing. All oil production emissions were spatially allocated by mapping to rural landuse.

For QA, the emission totals were reviewed following each step of EPS2 processing. Emissions density plots were reviewed for appropriate spatial distribution of emissions.

Point Sources

The 1996 emissions inventory developed by PS was used for the TLM domain. The point sources were extracted from a spreadsheet and processed using EPS2. The 1996 emissions were then adjusted to 1995 using TNRCC growth factors. The PS point source inventory only covers the 5 core counties and surrounding 17 counties. The TNRCC inventory was used for those sources in the TLM domain not provided by PS. In order not to double count emissions, the PS point sources were removed from the TNRCC inventory before processing.

Elevated and Low Level Points

When point sources are processed for CAMx using EPS2, each individual emission point (stack) is screened to determine whether it may have a significant plume rise (greater than 20 meters). Sources with significant plume rise are included in the elevated point source file. All other point sources are considered "low-level points" and are processed with the surface emissions (area, mobile, biogenic etc.).

Day Specific Emissions

Day specific emissions information was obtained for several major sources in the area surrounding TLM. In general, day specific information is available for major NOx point sources that were equipped with continuous emissions monitors (CEMs) during the period being modeled. These CEM data can be processed to obtain hourly NOx emissions. The TNRCC emission inventory for EGUs (described above) contained some day specific information of this type (TNRCC, 1988).

The following companies in the TLM area were contacted directly to request information on day specific emissions: Central and Southwest Services, LaGloria Oil and Gas, Texas Eastman and Texas Utilities.

Central and Southwest Services provided hourly NOx emissions for their Knox Lee, Pirkey, Welsh and Wilkes facilities (personal communication from Mr. Howard Ground).

LaGloria Oil and Gas reported (personal communication from Mr. Dale Rhoades) that due to the steady state nature of their facility operations, NOx emission levels tend to be constant. Activity logs for the June 18-23 and July 7-12, 1995 period showed no unusual events (e.g., unit shutdowns) and so Mr. Rhoades recommended using the emission levels reported in the PS inventory (Pollution Solutions, 1998). Activity logs for the July 14-18, 1997 period showed that the Rheniformer Unit (EPNs 74A&B, 75A&B) was shut down during this period. Therefore, Mr. Rhoades recommended using the emission levels reported in the PS inventory (Pollution Solutions, 1998) with the indicated EPNs removed.

Texas Eastman reviewed plant activity data and provided day specific NOx emissions for their facility (personal communication from Mr. Steve Zuiss).

Texas Utilities provided hourly NOx emissions for their Martin Lake, Monticello and Stryker Creek facilities (personal communication from Mr. Dick Robertson).

June 1995

The day specific emission levels (averaged over the June 18-23, 1995 period) used for CAMx modeling are compared in Table 4-7 to the emission levels reported in the PS inventory for 1996 (PS, 1998).

Table 4-7. Comparison of NOx emissions for specific companies within the TLM domain for June 1995 (tons per day).

Company	Account	Pollution Solutions 1996 Annual	June 1995 Day Specific
Central and Southwest Services	Knox Lee	5.08	5.53
	Pirkey	0.03	47.36
	Wilkes	17.74	15.49
	Welsh	40.58	41.28
La Gloria Oil & Gas		3.67	3.67
Texas Eastman		15.64	14.85
Texas Utilities	Stryker Creek	9.14	6.61
	Martin Lake	81.13	89.20
	Monticello	63.62	57.12

July 1995

The day specific emission levels for July 7, 1995 (there are minor variations for other episode days) used for CAMx modeling are compared in Table 4-8 to the emission levels reported in the PS inventory for 1996 (PS, 1998).

Table 4-8. Comparison of NOx emissions for specific companies within the TLM domain for July 1995 (tons per day).

Company	Account	1996 Annual	July 7, 1995 Day Specific
Central and Southwest Services	Knox Lee	5.08	5.72
	Pirkey	0.03	46.23
	Wilkes	17.74	15.22
	Welsh	40.58	42.69
La Gloria Oil & Gas		3.67	3.67
Texas Eastman		15.64	14.38
Texas Utilities	Stryker Creek	9.14	6.99
	Martin Lake	81.13	91.10
	Monticello	63.62	42.25

July 1997

The day specific emission levels (averaged over the July 14-18, 1997 period) used for CAMx modeling are compared in Table 4-9 to the emission levels reported in the PS inventory for 1996 (PS, 1998).

Table 4-9. Comparison of NOx emissions for specific companies within the TLM domain for July 1997 (tons per day).

Company	Account	1996 Annual	July 15, 1997 Day Specific
Central and Southwest Services	Knox Lee	5.08	5.76
	Pirkey	0.03	24.45
	Wilkes	17.74	10.82
	Welsh	40.58	51.58
La Gloria Oil & Gas		3.67	3.67
Texas Eastman		15.64	18.10
Texas Utilities	Stryker Creek	9.14	10.51
	Martin Lake	81.13	100.10
	Monticello	63.62	68.09

Facility Specific Point Source VOC Speciation Profiles

The emission inventories that form the basis for this study report total VOC emissions. During processing with EPS2, these total VOC emissions must be split into the individual VOC classes used in the CB4 mechanism. The VOC speciation profiles used in the EPS2 processing for this study were based on guidance from the TNRCC and EPA, with the exception of the facility specific profiles described below.

The PS point source inventory was based on 1996 emissions reported to the TNRCC point source database (PSDB). The PSDB also contains some information on VOC speciation. In a previous TNRCC project, ENVIRON used PSDB speciated VOC data to develop facility specific speciation profiles for the DFW area (ENVIRON, 1997). This project demonstrated that the TNRCC PSDB can be used to develop facility specific speciation profiles in some cases, but in other cases the PSDB information is too generalized to be of use.

For this study, the major point sources of VOCs identified in the PS inventory were Texas Eastman, LaGloria Oil and Gas, and International Paper. For these facilities, PS obtained speciated VOC data from the PSDB and the data were analyzed by ENVIRON. The speciated VOC emissions are summarized in Table 4-10.

Table 4-10. Speciated VOC data reported in the TNRCC PSDB for three major facilities in the TLM area (tons per year).

	International Paper	Texas Eastman	La Gloria
nonmethane voc-u	555.9	268.0	2001.7
organic acid-u		10.6	
alcohols-u		7.5	
n-butyl alcohol		30.6	
ethanol		137.4	
glycols-u		8.9	
ethylene glycol		19.4	
methoxy-2-acetoxypropane, 1-		10.6	
isobutanol		21.4	
isopropanol	6.4		
ethyl hexanol (2)		15.7	
methanol	1198.7		
cresol, o	6.0		
cresol	19.8		
n-propanol		25.3	
acetaldehyde		13.2	
butyraldehyde		29.6	
isobutyraldehyde		42.3	
ethyl-3-propyl acrolein, 2-		14.6	
propionaldehyde		26.8	
pinene, alpha-	17.3		
monoethanolamine		66.9	
terpene	838.8		
toluene			5.7
esters-u		23.6	
isobutyl acetate		68.1	
ethyl acetate		92.7	
propylene glycol monomethyl ether		5.3	
diethyl ether		54.8	
chloroform	5.3	12.4	
ethyl chloride		49.3	
methyl chloride		95.7	
butadiene		6.9	
butene		7.0	
ethylene		1485.3	
propylene		231.0	
hexene		10.8	
hexane		13.0	55.8
propane		186.5	
dimethyldisulfide	25.3		
methyl mercaptan	143.1		
dimethyl sulfide	78.5		
mineral spirits		6.3	

For La Gloria Oil and Gas and International Paper, the speciated VOC data reported in the PSDB were too generalized to develop speciation profiles that would be an improvement over the existing TNRCC/EPA profiles.

For the Texas Eastman facility, the PSDB data were analyzed to develop specific VOC speciation profiles for as many emission points as possible. The Texas Eastman VOC emissions shown in Table 4-10 include some "unidentified nonmethane VOC" coming mainly from sources that were internal combustion engines. Source specific profiles were not developed for these emissions because the TNRCC/EPA default profiles are suitable. For the remaining emission points, 74 VOC speciation profiles were developed in EPS2 format using the methods described in ENVIRON (1997). These profiles describe over 90 percent of the VOC emissions from the facility.

Plume-in Grid Treatment

As noted above, a single elevated point source file is required covering the entire CAMx domain. The separate point source files (PS data, Texas EGUs, other Texas sources, Louisiana sources, offshore sources, and all other sources) were merged and a complete list of elevated sources was generated. This list was then reviewed and the top NOx sources were flagged for PiG (plume-in-grid) treatment. Sources within the TLM domain having NOx emissions greater than one ton per day and all other NOx sources greater than 20 tpd were flagged for PiG treatment.

Mobile Sources

Mobile sources for the TLM domain were processed in EPS2 using a similar approach as for the regional domain with the exception that more detailed spatial allocation was used for the TLM 4 km grid. For the TLM domain gridding was based on road type. Urban and rural interstate and highway roads were gridded using transportation link data, other urban roads were gridded by population, and other rural roads were gridded by rural landuse coverage. The transportation link data was obtained from the USGS web site http://edcwww.cr.usgs.gov/glis/hyper/guide/100kdlgfig/states/TX.html.

Anthropogenic Surface Emission Totals

The total surface anthropogenic emissions for the TLM 4 km emissions grid are summarized in Tables 4-11 through 4-13 for the different episodes. The emission totals for area, non-road and point sources are for a typical weekend and weekday. The mobile source emissions are day specific because they depend upon temperature and the totals are for the day indicated. Tables 4-14 through 4-16 report emission totals for individual counties in the area immediately surrounding TLM. The day used in Tables 4-14 through 4-16 is July 15, 1997 (a weekday) and this same day is used as the basis for comparison in future year inventories below.

Table 4-11. Total surface anthropogenic emissions by major source category for TLM 4 km emissions grid for June 1995 (tons per day).

Major Source Category	6/18/1995 Sunday			6/20/95 Tuesday		
	NOx	VOC	CO	NOx	VOC	CO
Area and Nonroad Sources	186.2	614.7	1609.0	271.9	511.8	1101.1
Mobile Sources	222.4	134.2	1188.4	221.7	143.3	1226.7
Low Level Point Sources	12.5	48.4	6.8	12.7	51.3	7.1
Total Low Level Anthropogenics	421.1	797.3	2804.2	506.3	706.4	2334.9

Table 4-12. Total surface anthropogenic emissions by major source category for TLM 4 km emissions grid for July 1995 (tons per day).

Major Source Category	07/07/95 Weekday			07/08/95 Saturday		
	NOx	VOC	CO	NOx	VOC	CO
Area and Nonroad Sources	271.9	511.8	1101.1	233.6	642.1	1638.8
Mobile Sources	221.5	148.5	1244.8	165.9	116.4	957.0
Low Level Point Sources	12.8	51.4	7.1	12.6	49.4	6.9
Total Low Level Anthropogenics	506.2	711.8	2353.0	412.1	808.0	2602.7

Table 4-13. Total surface anthropogenic emissions by major source category for TLM 4 km emissions grid for July 1997 (tons per day).

Major Source Category	7/15/97 Tuesday		
	NOx	VOC	CO
Area and Nonroad Sources	275.3	518.3	1113.1
Mobile Sources	212.2	135.9	1120.9
Low Level Point Sources	12.9	51.8	7.2
Total Low Level Anthropogenics	500.4	706.0	2241.2
Total Elevated Point Sources	578.6	47.5	119.6

Table 4-14. Anthropogenic NOx emissions by major source category and county for the TLM area for July 15, 1997 (tons per day).

FIPS	State	County Name	Area	Non-Road*	On-Road Mobile	Low Points	Total Low Anthro	Elevated Points
48001	TX	Anderson	3.7		3.7		7.4	0.2
48037	TX	Bowie	6.4		13.7	0.0	20.1	0.7
48063	TX	Camp	0.9		0.8	0.0	1.7	0.1
48067	TX	Cass	2.5		3.6	0.0	6.2	7.0
48073	TX	Cherokee	3.3		3.6	0.0	6.9	10.5
48159	TX	Franklin	0.8		1.4	0.0	2.2	
48183	TX	Gregg	11.4	3.3	8.5	0.5	23.8	11.1
48203	TX	Harrison	7.4	4.4	11.7	2.5	26.0	42.1
48213	TX	Henderson	4.6		5.1	0.4	10.2	12.3
48223	TX	Hopkins	2.9		4.3	1.0	8.2	0.4
48315	TX	Marion	1.2		1.2	0.0	2.4	12.1
48343	TX	Morris	1.1		1.8	0.3	3.2	1.6
48347	TX	Nacogdoches	3.9		5.7	0.3	9.9	1.0
48365	TX	Panola	1.9		4.0	0.9	6.8	13.7
48379	TX	Rains	0.7		0.7	0.0	1.4	0.0
48387	TX	Red River	2.0		1.2	0.0	3.2	
48401	TX	Rusk	7.9	1.1	5.4	0.3	14.8	100.3
48419	TX	Shelby	1.8		2.4	0.0	4.2	0.7
48423	*TX*	*Smith*	*5.0*	*5.1*	*15.2*	*0.2*	*25.6*	*4.0*
48449	TX	Titus	1.8		4.3	0.0	6.1	119.6
48459	TX	Upshur	7.8	2.6	2.8	0.0	13.1	0.0
48467	TX	Van Zandt	3.4		6.8	0.0	10.2	4.6
48499	TX	Wood	2.5		2.0	0.5	5.0	5.5
5091	AR	Miller	3.3		4.3	0.0	7.6	0.2
22015	LA	Bossier	12.1		8.4	1.4	21.9	3.3
22017	LA	Caddo	*69.8*		*22.9*	*0.8*	*93.5*	*5.5*

* Nonroad emissions are included in 'Area' for all counties outside the NETAC 5 county inventory

Table 4-15. Anthropogenic VOC emissions by major source category and county for the TLM area for July 15, 1997 (tons per day).

FIPS	State	County Name	Area	Non-Road*	On-Road Mobile	Low Points	Total Low Anthro	Elevated Points
48001	TX	Anderson	9.7		3.0	0.6	13.3	0.0
48037	TX	Bowie	21.4		7.1	0.4	28.9	0.5
48063	TX	Camp	3.2		0.5	0.0	3.8	0.0
48067	TX	Cass	7.8		2.2	2.1	12.1	4.3
48073	TX	Cherokee	9.5		2.6	0.3	12.4	0.1
48159	TX	Franklin	3.6		0.8	0.0	4.4	
48183	TX	Gregg	71.8	7.0	7.9	2.9	89.7	0.7
48203	TX	Harrison	9.6	9.0	5.6	9.8	33.9	4.4
48213	TX	Henderson	18.6		3.4	1.0	23.1	0.4
48223	TX	Hopkins	5.5		3.0	0.2	8.7	0.1
48315	TX	Marion	3.4		0.7	0.2	4.2	0.5
48343	TX	Morris	4.2		1.0	0.8	6.0	0.0
48347	TX	Nacogdoches	17.6		3.9	0.9	22.4	3.7
48365	TX	Panola	17.1		2.2	2.9	22.2	0.5
48379	TX	Rains	2.6		0.5	0.0	3.1	0.0
48387	TX	Red River	4.6		0.8	0.0	5.4	
48401	TX	Rusk	22.9	4.9	3.3	1.0	32.1	1.5
48419	TX	Shelby	6.0		1.5	0.4	7.9	0.0
48423	TX	Smith	18.1	15.8	11.8	7.2	52.9	1.0
48449	TX	Titus	6.0		2.3	0.2	8.5	2.8
48459	TX	Upshur	7.7		1.8	0.5	10.0	0.2
48467	TX	Van Zandt	8.2	5.0	3.8	0.8	17.8	0.2
48499	TX	Wood	7.9		1.6	0.8	10.3	0.2
5091	AR	Miller	7.1		3.2	0.0	10.3	0.0
22015	LA	Bossier	12.0		6.4	1.5	19.8	0.3
22017	LA	Caddo	44.2		18.6	2.8	65.5	2.2

* Nonroad emissions are included in 'Area' for all counties outside the NETAC 5 county inventory

Table 4-16. Anthropogenic CO emissions by major source category and county for the TLM area for July 15, 1997 (tons per day).

FIPS	State	County Name	Area	Non-Road*	On-Road Mobile	Low Points	Total Low Anthro	Elevated Points
48001	TX	Anderson	27.3		21.3	0.0	48.6	0.1
48037	TX	Bowie	66.3		59.3	0.0	125.6	1.3
48063	TX	Camp	9.5		3.9	0.0	13.4	0.1
48067	TX	Cass	26.3		16.0	0.1	42.4	3.5
48073	TX	Cherokee	26.0		18.6	0.0	44.7	1.8
48159	TX	Franklin	6.5		7.4	0.0	13.9	
48183	TX	Gregg	2.7	50.9	61.2	0.4	115.3	3.2
48203	TX	Harrison	2.1	40.7	50.0	1.1	94.0	3.7
48213	TX	Henderson	49.8		25.1	0.1	75.0	3.1
48223	TX	Hopkins	15.7		27.3	0.4	43.4	0.3
48315	TX	Marion	11.0		5.0	0.0	16.0	2.2
48343	TX	Morris	9.0		8.4	0.1	17.5	3.9
48347	TX	Nacogdoches	41.1		28.7	0.0	69.8	1.5
48365	TX	Panola	19.0		16.1	0.4	35.5	5.2
48379	TX	Rains	6.4		3.7	0.0	10.0	0.1
48387	TX	Red River	15.0		5.8	0.0	20.8	
48401	TX	Rusk	2.6	25.8	24.4	0.2	53.1	4.9
48419	TX	Shelby	15.6		10.8	0.0	26.4	0.1
48423	TX	Smith	2.3	90.2	93.9	1.3	187.7	3.0
48449	TX	Titus	16.1		20.4	0.0	36.5	9.6
48459	TX	Upshur	1.8		13.0	0.0	14.8	0.1
48467	TX	Van Zandt	21.2	22.3	37.0	0.0	80.5	1.5
48499	TX	Wood	21.9		11.4	0.3	33.6	1.6
5091	AR	Miller	15.6		24.0	0.0	39.6	0.3
22015	LA	Bossier	37.0		48.2	1.0	86.2	0.9
22017	LA	Caddo	102.0		137.5	0.3	239.7	1.3

* Nonroad emissions are included in 'Area' for all counties outside the NETAC 5 county inventory

Biogenic Emissions for Base Case 1

Day-specific gridded biogenic emissions for the TLM emissions grid were based on a combination of GLOBEIS and BEIS2. The development of the GLOBEIS locally specific biogenic emission inventory is described in ENVIRON (1999). Briefly, the GLOBEIS emissions use an enhanced, locally-specific biomass density database with an updated version of BEIS2 (called GLOBEIS) that can utilize the local data. GLOBEIS generated biogenic emissions were available for most of the Texas counties within the TLM 4-km emissions grid. Biogenic emissions for the remaining areas (Louisiana, Arkansas, Oklahoma and a few Texas counties) were generated using the BEIS2 system described above for the regional emissions grid. The two biogenic inventories were then merged so that the GLOBEIS emissions were used wherever available with the BEIS2 emissions filling in around the outside of the area covered by GLOBEIS.

June 1995

The hourly, gridded temperatures were from the SAIMM meteorological model adjusted two degrees higher, as described above for the regional emissions grid.

Table 4-17. Base case 1 biogenic emissions for TLM 4km emissions grid for June 1995 (tons per day).

	VOC	NOx
June 18	9931	46
June 19	10771	47
June 20	11438	50
June 21	12419	53
June 22	12115	51
June 23	12132	51

July 1995

The hourly, gridded temperatures were from the RAMS meteorological model, as described above for the regional emissions grid.

Table 4-18. Base case 1 biogenic emissions for TLM 4km emissions grid for July 1995 (tons per day)

	VOC	NOx
July 7	12487	53
July 8	13645	56
July 9	13563	56
July 10	14222	58
July 11	14910	60
July 12	14748	59

July 1997

Hourly temperature observations from Tyler and Longview were used to generate the hourly, gridded temperatures for biogenic processing. An average of the two observed measurements was computed and distributed throughout the grid. Of particular interest in this modeling episode is the large temperature drop just after noon on July 15, 1997 which corresponds to heavy cloud cover during this period. Since biogenic emissions are strongly temperature dependent it would seem likely that this temperature drop would have an impact on estimated biogenic emissions. This is indeed the case. A review of Table 6, daily biogenic totals, indicates that July 15 VOC is less than 70% of the previous day.

Table 4-19. Base case 1 biogenic emissions for TLM 4km emissions grid for July 1997 (tons per day).

	VOC	NOx
July 14	11345	52
July 15	7513	43
July 16	10511	49
July 17	11075	51
July 18	10988	51

BASE CASE 2 BIOGENIC EMISSIONS

During the course of this project ENVIRON completed development of a new version of the GLOBEIS biogenic emissions model, called GLOBEIS2. The development of GLOBEIS2 was sponsored by the TNRCC and involved collaboration between ENVIRON, the National Center for Atmospheric Research (NCAR) and the University of Texas at Austin. GLOBEIS contains the latest biogenic emissions modeling algorithms developed at NCAR in a flexible modeling framework that allows use of LULC data from many different sources. For this study, the LULC data were a combination of the local surveys for East Texas (and other areas of Texas) with the latest EPA BELD database for surrounding states. The development of the GLOBEIS2 model and LULC data are described in ENVIRON (1999).

The LULC data for GLOBEIS2 were processed for the regional emissions grid at 16 km resolution. Day specific emission inventories were prepared using the same temperature assumptions as for base case 1, described above. To obtain biogenic emissions for the TLM 4 km emissions grid, the 16 km regional emissions were extracted and re-mapped to 4 km resolution. GLOBEIS2 could be run at 4 km resolution to develop inventories for the TLM 4 km grid with improved spatial resolution, however, there was insufficient time and resources to accomplish this in this study.

The base case 2 biogenic emissions are summarized in Tables 4-20 through 4-22 for the June 1995 and July 1997 episodes. GLOBEIS2 generally reduces biogenic emission levels by about 30% relative to the BEIS2 emissions algorithms used in base case 1, however, direct comparisons between the biogenic emissions for base case 1 and 2 are complicated by updates tot he LULC data as well as the emission factor model. No base case 2 inventories were prepared for the July 1995 episode because it had been dropped from the modeling at this point in time.

Table 4-20. Base case 2 biogenic emissions by day for the regional emissions grid for June 1995 (tons per day)

	VOC	NOx
June 18	71160	1989
June 19	74979	2045
June 20	73026	2043
June 21	78767	2082
June 22	82914	2111
June 23	86577	2147

Table 4-21. Base case 2 biogenic emissions for the TLM 4km emissions grid for June 1995 (tons per day)

	VOC	NOx
June 18	7519	46
June 19	7418	46
June 20	6479	43
June 21	7114	46
June 22	7839	49
June 23	9154	52

Table 4-22. Base case 2 biogenic emissions for the TLM 4km emissions grid for July 1997 (tons per day).

	VOC	NOx
July 14	9481	53
July 15	6620	44
July 16	8774	50
July 17	9256	53
July 18	9136	53

FUTURE YEAR BASE CASE

In general, the future year emission inventories were prepared by adjusting the base year inventories for the effects of "growth and controls." Growth means the change in the levels of anthropogenic activity leading to emissions between the base and future year, and generally (but not always leads) to an increase in emissions. Controls means the change in emission levels due to changes in the equipment involved in emissions processes. Controls may be the addition of specific control equipment to existing, long-lived industrial equipment (e.g., the addition of scrubbers), or they may be the retirement of older technology equipment and replacement by newer, inherently cleaner technology (e.g., the impact of fleet turnover coupled with new regulations for motor vehicles). Only control measures for which regulations are currently "on-the-books" were included in the future year base case.

The main source of information on growth and controls was the analysis performed by EPA in support of the NOx SIP call. The NOx SIP call projected emissions to 2007 for the all the states in the Eastern U.S., and therefore included information for all areas in the regional emissions modeling grid for this study. The specific information used for this study was from "Round 3" as specified in the data files posted on EPA's FTP site at "/pub/scram001/modelingcenter/NOx_SIPcall/emissions/." The growth and controls assumptions are described by source category in Table 4-23.

Table 4-23. Sources of information for 2007 growth and controls.

Category	Growth	Controls
Area & Nonroad Sources	Growth factors for area and nonroad sources from the EPA NOx SIP call round3	Control factors for area sources from the EPA NOx SIP call round3. Control factors for nonroad sources from the EPA NONROAD model
Mobile Sources	Texas - VMT growth factors from TNRCC. Other States – VMT growth from the EPA NOx SIP call round3.	Emission factors from the EPA MOBILE5 model – same methodology as the EPA NOx SIP call.
Point Sources – except major sources in East Texas	Texas EGU emission rates for 2007 from the EPA NOx SIP call round3. Growth factors for point sources from the EPA NOx SIP call round3.	Control factors for point sources (by county and SCC) from the EPA NOx SIP call round3.
Major Point Sources in East Texas	Hold emissions at 1997 summer seasonal levels and add new sources with permits.	Facility specific control measures were evaluated in the control strategy development.
Texas Nonattainment Areas (Houston, Beaumont, Dallas/Fort-Worth)		Across the board reductions to approximate SIP reductions that will be in place by 2007.
Biogenic Emissions	No change	Not applicable.

Cases where the NOx SIP call assumptions for growth and controls were not used are discussed below.

Nonroad emissions: control factors for nonroad sources were calculated for each equipment type using the EPA's NONROAD model because this model contains up-to-date information on the phase-in of new emissions standards for nonroad sources between the base years and 2007.

Texas Mobile Sources: growth factors for mobile source emissions in Texas were based on guidance from the TNRCC.

Texas EGUs: base year emission rates for electrical generating units (EGUs) in Texas were based on day specific historical data. Since it is not appropriate to project day specific historical data to a future year, the future year emission levels for EGUs in Texas were from the NOx SIP call inventory.

Texas Nonattainment Areas: Source category specific control strategies were not available for the Texas nonattainment areas at the time this study was performed. However, the TNRCC had completed across the board emission reductions to identify the level of controls needed to demonstrate ozone attainment. Therefore, for the nonattainment area counties the following across the board emission reductions were applied to approximate the emission reductions that will be realized when the SIPs are finalized:

Dallas/Ft Worth 4 county area: reduce VOC 25% and NOx 50%.
Houston/Galveston 8 county area: reduce VOC 20% and NOx 75%.
Beaumont/Port Arthur 3 county area: reduce VOC 10% and NOx 40%.

East Texas Point Sources

The EPA NOx SIP call growth and control assumptions were evaluated for several major point sources in east Texas. This evaluation identified two significant problems:

- Emissions decreases for several major point sources
- The assumption that new units had been constructed at several EGUs

Accordingly, it was decided not to base the future year emissions for major point sources in East Texas on the assumptions in the EPA NOx SIP call inventory.

The NETAC technical committee reviewed assumptions for future year emissions from major point sources in East Texas. Since all of the sources will retain their current capacity, it was decided that there would be no significant emissions decreases unless control measures were instituted. The most recent year for which emissions data were available was 1997. In the summer of 1997 sources were operating close to full capacity such that there is no significant potential for emissions increases without adding production capacity. Any growth in production capacity would require that new emissions be offset by reductions elsewhere. Therefore, it was decided to assume that 2007 emissions would remain at typical summer 1997 levels.

Information on typical summer 1997 emission levels was provided by the companies operating each facility. The main difference between 2007 typical emissions levels and the levels previously reported for the July 14-18, 1997 period was that any unusual day specific events (e.g., units being shut down) were removed from the typical summer day inventory. The 2007 NOx emission levels for major point sources are compared to 1997 day specific levels in Table 4-28. The 2007 levels are higher than the 1997 levels for five of nine facilities, and do not change or decrease slightly at the remaining four facilities. The locations of the facilities named in Table 4-24 are shown in Figure 4-3. Figure 4-4 shows the locations and emission rates of all elevated NOx point sources with 2007 base case emissions greater than 2 tons/day in the TLM 4 km grid.

There are two point sources in East Texas that have received permits but not yet been built – Southland and Tenaska. Emissions from these sources were included in the 2007 base case (Table 4-24) at levels estimated from the permits filed with the TNRCC (personal communication from Jocelyn Mellberg, TNRCC).

Table 4-24. Summary of NOx emissions (tons per day) for major point sources.

Company	Account	Name	2007 (All Days)	1997 (July 15)	% Change
CSW	GJ0043K	Knox Lee	7.1	5.8	24
CSW	HH0037F	Pirkey	25.4	24.5	4
CSW	TF0012D	Welsh	65.7	51.6	27
CSW	ME0006A	Wilkes	12.6	10.8	16
Tenaska		Gateway	3.8		
LaGloria	SK0022A		3.6	3.6	0
Eastman	HH0042M		17.9	18.1	-1
TXU	RL0020K	Martin Lake	98.1	100.1	-2
TXU	TF0013B	Monticello	66.1	68.1	-3
TXU	CJ0026J	Stryker Creek	15.2	10.5	44
Southland			0.4		
Total			315.9	293.1	8

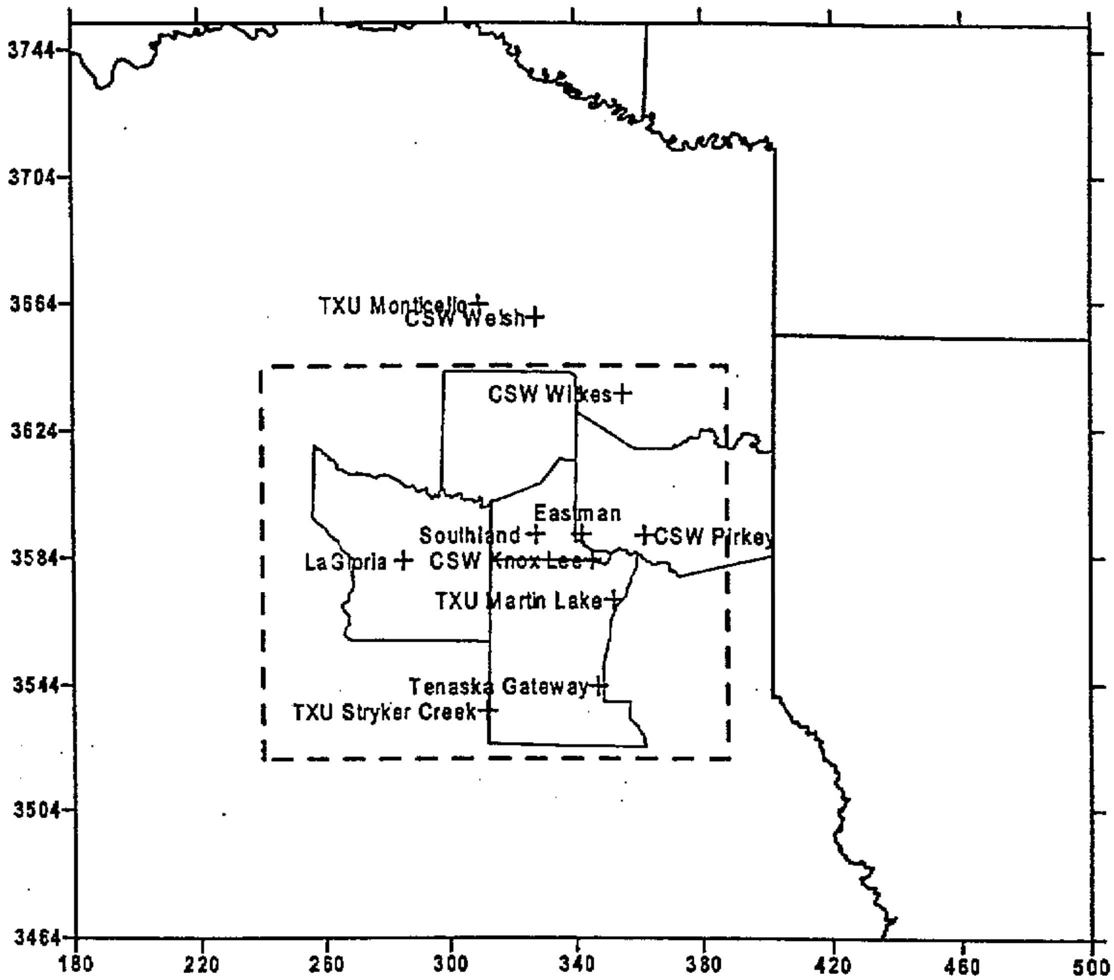


Figure 4-3. Name and location of major point sources in East Texas.

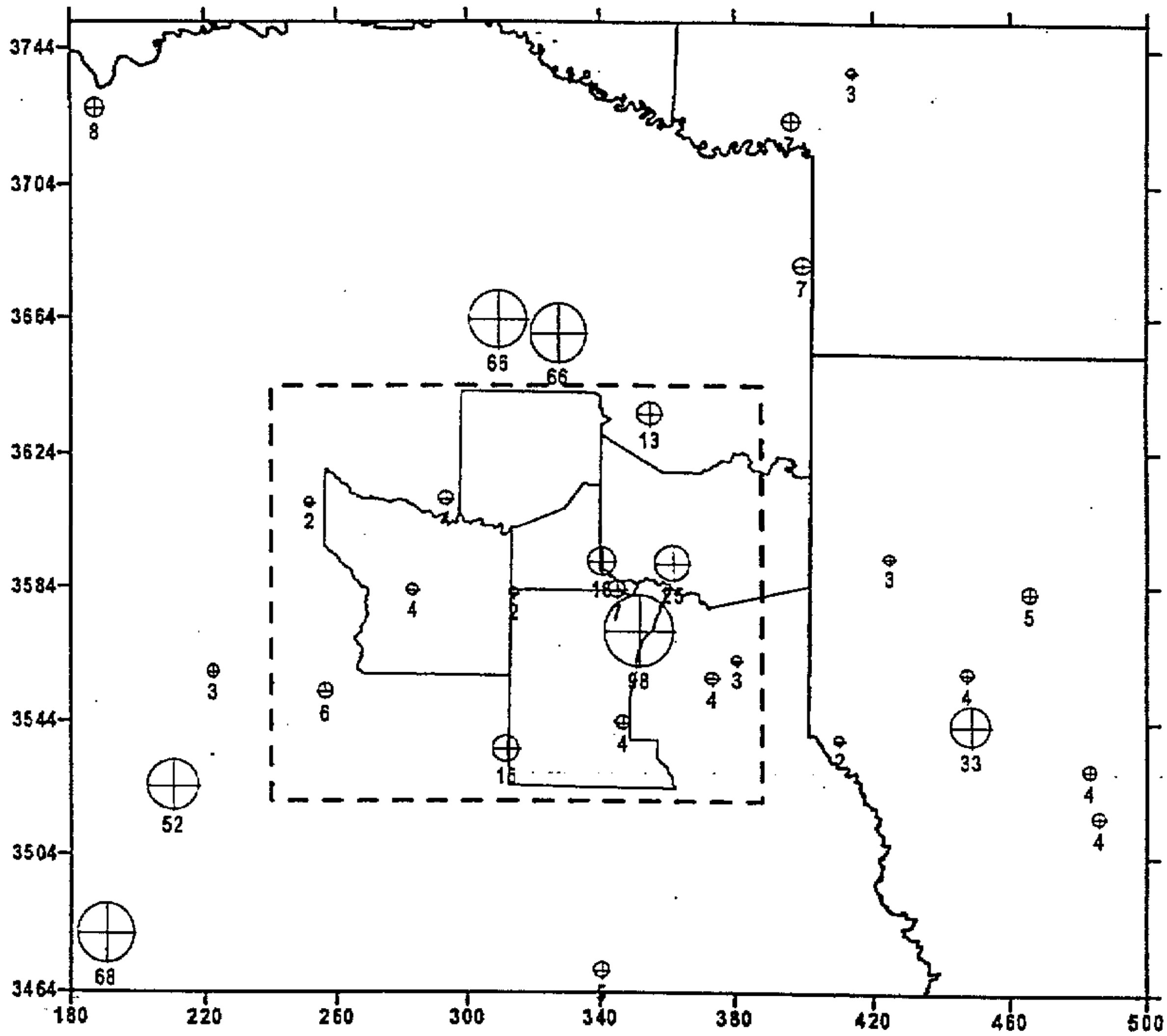


Figure 4-4. 2007 base case emissions of NOx (tons/day) for all elevated point sources greater than 2 tons/day in the TLM 4km domain. Emissions from multiple stacks at the same facility have been aggregated.

County level NOx and VOC emissions for the five NETAC counties and the two LA Parishes surrounding Shreveport are compared in Tables 4-25 and 4-26. Generally, there are small decreases in total low level NOx emissions between 1997 and 2007 in large part due to decreases for on-road mobile and non-road sources which result from the phase in of newer technology vehicles and equipment. The on-road mobile emissions for 2007 assume NLEV vehicles with emission reductions estimated using MOBILE5B, but do not include any cleaner burning gasoline.

Total low level VOC emissions show larger decreases between 1997 and 2007 than do NOx emissions. VOC emissions from on-road mobile and non-road sources also decrease due to the phase in of newer technology vehicles and equipment. The largest VOC reductions are for area sources resulting from national level control programs. The effect of these controls were modeled using source specific control factors developed by the EPA for the NOx SIP call.

Table 4-25. 2007 base case anthropogenic NOx emissions (tons per day) by major source category and county.

FIPS	State	County Name	Area	Non-Road*	On-Road Mobile	Low Points	Total Low Anthro	Elevated Points
2007 Base Case								
48183	TX	Gregg	10.5	2.8	7.4	0.4	21.1	12.5
48203	TX	Harrison	6.4	3.4	10.1	2.4	22.3	42.8
48401	TX	Rusk	6.8	1.0	4.3	0.3	12.4	102.0
48423	TX	Smith	5.4	4.3	13.8	0.2	23.7	3.9
48459	TX	Upshur	6.5	1.9	2.4	0.0	10.9	0.0
22015	LA	Bossier	10.3		7.5	1.5	19.4	3.3
22017	LA	Caddo	62.5		20.6	0.7	83.7	5.4
Year 1997								
48183	TX	Gregg	11.4	3.3	8.5	0.5	23.8	11.1
48203	TX	Harrison	7.4	4.4	11.7	2.5	26.0	42.1
48401	TX	Rusk	7.9	1.1	5.4	0.3	14.8	100.3
48423	TX	Smith	5.0	5.1	15.2	0.2	25.6	4.0
48459	TX	Upshur	7.8	2.6	2.8	0.0	13.1	0.0
22015	LA	Bossier	12.1		8.4	1.4	21.9	3.3
22017	LA	Caddo	69.8		22.9	0.8	93.5	5.5

* Nonroad emissions are included in 'Area' for counties in LA.
Mobile source totals are day specific for July 15, 1997.

Table 4-26. 2007 base case anthropogenic VOC emissions (tons per day) by major source category and county.

FIPS	State	County Name	Area	Non-Road*	On-Road Mobile	Low Points	Total Low Anthro	Elevated Points
2007 Base Case								
48183	TX	Gregg	37.5	4.5	6.4	1.7	50.0	0.4
48203	TX	Harrison	5.9	7.0	4.5	9.7	27.1	8.2
48401	TX	Rusk	12.1	3.7	2.5	1.1	19.4	15.6
48423	TX	Smith	13.1	11.4	10.0	7.0	41.5	0.9
48459	TX	Upshur	4.4	4.0	1.5	0.5	10.3	0.2
22015	LA	Bossier	8.7		5.3	1.5	15.4	0.3
22017	LA	Caddo	30.5		15.4	1.2	47.1	1.7
Year 1997								
48183	TX	Gregg	71.8	7.0	7.9	2.9	89.7	0.7
48203	TX	Harrison	9.6	9.0	5.6	9.8	33.9	4.4
48401	TX	Rusk	22.9	4.9	3.3	1.0	32.1	1.5
48423	TX	Smith	18.1	15.8	11.8	7.2	52.9	1.0
48459	TX	Upshur	7.7		1.8	0.5	10.0	0.2
22015	LA	Bossier	12.0		6.4	1.5	19.8	0.3
22017	LA	Caddo	44.2		18.6	2.8	65.5	2.2

* Nonroad emissions are included in 'Area' for counties in LA.
Mobile source totals are day specific for July 15, 1997.

REVISED 2007 BASE CASE

The revised 2007 base case included the estimated impacts of Federal control programs that can reasonably be expected to be in place by 2007. The Federal programs to be included were:

- Tier2 vehicles and fuels. Tier2 cars and trucks will have tighter emission standards than NLEVs and will begin phase-in with the 2004 model year. These vehicles are expected to be accompanied by a low sulfur fuel that would supercede proposed Texas clean gasolines, such as TCAS fuel.
- 2004 Heavy Duty Diesel standards. Tighter emission standards for heavy duty diesel trucks will begin in 2004.
- New locomotive emission standards. Tighter emission standards for railway locomotives began in 1998.

These reductions were applied over the area of the 4 km grid only. This will account for almost all of the ozone benefits in East Texas and avoids any difficulties of potential "double counting" of emission reductions between these measures and the Houston/Dallas SIP reductions already included in the future year base case inventories. The estimated emissions reductions due to these measure are summarized in Table 4-27, and the impact on county level emissions is shown in Tables 4-28 and 4-29. Taking Smith County NOx emissions as an example, Tier2 vehicles and fuels combined with HDD vehicle standards reduce 2007 mobile source NOx emissions from 13.8 to 11.6 tons/day (comparing Tables 4-25 and 4-28). The new locomotive emission standards reduce nonroad emissions from 4.3 to 3.8 tons/day.

Table 4-27. Federal control programs included in the revised base case

Measure	Impact on 2007 Emission Inventory
Tier 2 Vehicles and Fuels	Reductions in fleet average mobile source emissions of 12.6% for NOx and 11.5% for VOC. These impacts were estimated for Dallas areas without inspection and maintenance programs (I/M) by Radian for the TNRCC.
2004 HDD Vehicle Standards	Reductions in fleet average mobile source emissions of 3.1% for NOx. Impact calculated by ENVIRON based on EPA guidance.
New locomotive emission standards	Reduction in NOx emissions from diesel railway locomotives of 36%. Impact calculated by ENVIRON based on EPA fact sheet.

Table 4-28. 2007 revised base case anthropogenic NOx emissions (tons per day) by major source category and county.

FIPS	State	County Name	Area	Non-Road*	On-Road Mobile	Low Points	Total Low Anthro	Elevated Points
2007 Revised Base Case								
48183	TX	Gregg	10.5	2.5	6.2	0.4	19.6	12.5
48203	TX	Harrison	6.4	2.6	8.5	2.4	19.9	42.8
48401	TX	Rusk	6.8	.9	3.6	0.3	11.6	102.0
48423	TX	Smith	5.4	3.8	11.6	0.2	21.0	3.9
48459	TX	Upshur	6.5	1.5	2.0	0.0	10.0	0.0
22015	LA	Bossier	9.9		6.3	1.5	17.7	3.3
22017	LA	Caddo	61.2		17.3	0.7	79.2	5.4
Year 1997								
48183	TX	Gregg	11.4	3.3	8.5	0.5	23.8	11.1
48203	TX	Harrison	7.4	4.4	11.7	2.5	26.0	42.1
48401	TX	Rusk	7.9	1.1	5.4	0.3	14.8	100.3
48423	TX	Smith	5.0	5.1	15.2	0.2	25.6	4.0
48459	TX	Upshur	7.8	2.6	2.8	0.0	13.1	0.0
22015	LA	Bossier	12.1		8.4	1.4	21.9	3.3
22017	LA	Caddo	69.8		22.9	0.8	93.5	5.5

* Nonroad emissions are included in 'Area' for counties in LA.
Mobile source totals are day specific for July 15, 1997.

Table 4-29. 2007 revised base case anthropogenic VOC emissions (tons per day) by major source category and county.

FIPS	State	County Name	Area	Non-Road*	On-Road Mobile	Low Points	Total Low Anthro	Elevated Points
2007 Revised Base Case								
48183	TX	Gregg	37.5	4.5	5.6	1.7	49.3	0.4
48203	TX	Harrison	5.9	7.0	4.0	9.7	26.6	8.2
48401	TX	Rusk	12.1	3.7	2.2	1.1	19.1	15.6
48423	TX	Smith	13.1	11.4	8.9	7.0	40.4	0.9
48459	TX	Upshur	4.4	4.0	1.3	0.5	10.2	0.2
22015	LA	Bossier	8.7		4.7	1.5	14.9	0.3
22017	LA	Caddo	30.5		13.6	1.2	45.3	1.7
Year 1997								
48183	TX	Gregg	71.8	7.0	7.9	2.9	89.7	0.7
48203	TX	Harrison	9.6	9.0	5.6	9.8	33.9	4.4
48401	TX	Rusk	22.9	4.9	3.3	1.0	32.1	1.5
48423	TX	Smith	18.1	15.8	11.8	7.2	52.9	1.0
48459	TX	Upshur	7.7		1.8	0.5	10.0	0.2
22015	LA	Bossier	12.0		6.4	1.5	19.8	0.3
22017	LA	Caddo	44.2		18.6	2.8	65.5	2.2

* Nonroad emissions are included in 'Area' for counties in LA.
Mobile source totals are day specific for July 15, 1997.

5. BASE YEAR OZONE MODELING

This section of the report describes the development of ozone models for three historical episodes:

- June 18-23, 1995
- July 14-18, 1997
- July 7-12, 1995

Modeling was performed using the Comprehensive Air quality Model with extensions (CAMx) version 2.0. The preparation of model input data for CAMx is described in preceding Sections of this report. The goals of the base year modeling were to:

- Evaluate the performance of CAMx in describing ozone formation for each episode.
- Develop a base case model for each episode that can be used to predict how ozone will change in response to changes in emission.

The final base case modeling scenarios described at the end of this section serve as the basis for the future year modeling described in Section 6.

OVERVIEW

The presentation of the base case modeling in this section follows the chronology of the work, and is broken down by episode. First, there is a review of the approaches to model performance evaluation used in this study, including the specifications for the diagnostic and sensitivity tests. Then, the preliminary base case model performance evaluation plus diagnostic and sensitivity testing is described for each episode. For the July 1997 episode, aircraft data were available for July 17 and the evaluation against these data is described in a separate section.

For June 1995 and July 1997 episodes acceptable model performance was obtained for four days:

- June 22 and 23, 1995
- June 16 and 17, 1997

These days formed the basis of future year control strategy evaluation described in Section 6 of this report.

The July 1995 episode had serious model performance problems which are described in the discussion of diagnostic and sensitivity testing for this episode. Some explanations for these performance problems were developed, and performance was improved, but ultimately it was decided not to proceed with using the July 1995 episode for future year modeling and control strategy development.

Based on the diagnostic testing of the July 1995 episode it was decided to compare model predicted isoprene levels to observed values at Longview. This is not a straightforward comparison because the only available isoprene data are for 1998, whereas the modeling was performed for 1995 and 1997. The isoprene evaluation strongly suggested that the biogenic emission levels were too high in the base case modeling. Therefore, alternate base case biogenic emission inventories were developed using (1) across-the-board reductions and (2) a newer biogenic emissions model (GLOBEIS2). The final base cases for the June 1995 and July 1997 episodes used the GLOBEIS2 biogenic emissions estimates. The isoprene evaluation and the development of final base cases are described at the end of this section.

AIR QUALITY DATA

The ozone monitoring sites in the 4 km grid are listed in Table 5-1. Data were available for all three episodes from four sites: GGGC, TX47, LA02 and LA07. The TX47 site fist began operation in 1995 and data completeness at this site is lower than for the other sites. The PLST site was a special study site operated in 1997 only. The TNRCC CAMS50 at the Cypress River Airport in Marion County was not in operation during 1995-97. The locations of these sites are shown in Figure 5-1.

There were no sites in the 4 km grid collecting ozone precursor data during 1995-97.

Table 5-1. Ozone monitoring sites located in the 4 km grid.

Site Code	AIRS ID	TNRCC ID	UTM Easting	UTM Northing	Description
GGGC	481830001	CAMS19	339.4	3583.2	Not in a city, Gregg Co., Texas
TX47	484230004	CAMS86	273.6	3582.1	Tyler, Smith Co., Texas
LA02	220150008	N/A	430.2	3599.7	Shreveport, Bossier Par., Louisiana
LA07	220170001	N/A	419.8	3615.1	Not in a city, Caddo Par., Louisiana
PLST	N/A	N/A	249.3	3516.3	Palestine, Anderson Co., Texas

Monitoring locations in the 4 km grid during 1995 and sub-domain for the model performance evaluation of peak ozone (dashed line)

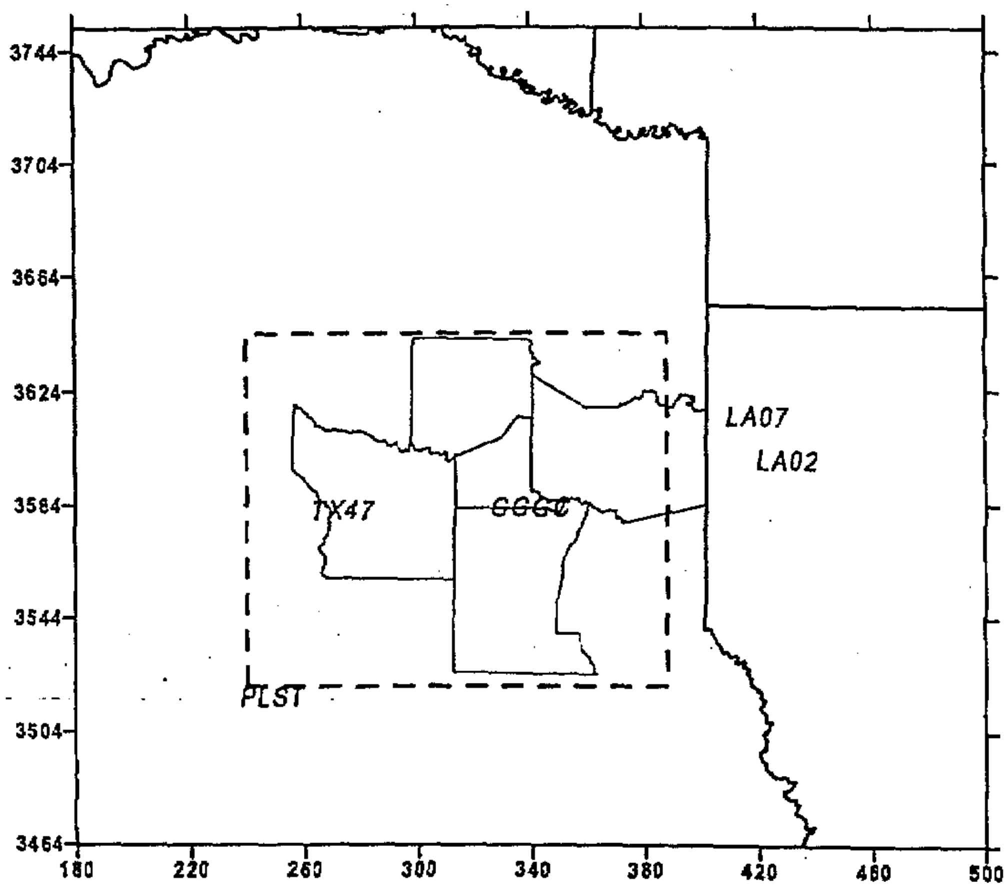


Figure 5-1. Monitoring locations and the Tyler-Longview-Marshall model performance sub-domain (dashed box).

APPROACH TO MODEL PEFORMANCE EVALUATION

The base case model performance for each episode was evaluated using EPA-guidance statistical procedures and graphical analyses for comparing predicted ozone concentrations to observed values.

Graphical Methods

Graphical displays comparing predicted to observed concentrations can provide information on model performance. The following techniques were used for days subsequent to the ramp-up day:

- Time-Series Plots. For each monitoring station in the domain and for each hour in the episode, the predicted concentration was compared with the monitored concentration. This is useful to determine if the model can predict the peak concentrations and if the timing of ozone generation in the model agrees with that found with the monitoring. Because modeled concentrations are compared with data from monitoring sites, which are specific points in space, it should not be expected that agreement will be excellent, although some fundamental agreement is required in order to determine, in part, that the model is accurately simulating the formation of ozone.

- Surface-Level Isopleths. Surface-level isopleths (lines of equal concentration) were drawn on a map for the daily maximum concentration. The observed daily maximum concentrations were also shown on the same map. This shows how the model is predicting the extent, location, and magnitude of ozone formation.

Statistical Methods

Statistical analyses can provide quantitative measures of model performance. The results of these methods must be considered carefully, especially in cases (like East Texas) where there are relatively few ozone monitors. Three statistical measures are specifically identified in EPA guidance:

- Unpaired accuracy of the peak (peak domain maximum). This measure compares the difference between the highest observed value and the highest predicted value found over all hours and over all monitoring stations. This statistic is the weakest of the three recommended measures since it only compares a single pair of values.

  $$\textit{Unpaired Accuracy of the Peak} = 100\,(O_u - E_u)/O_u$$

  Where O_u and E_u are, respectively, the observed and estimated maximum ozone concentrations (unmatched by time and location) for a particular region and day.

- Normalized Bias. This test measures the model's ability to replicate observed patterns. Since there are many time periods when relatively low levels of ozone are predicted, and statistics from these periods are not very meaningful, this test will be limited to pairs where the observed concentration is greater than 60 ppb. This threshold is notably above the naturally occurring background value of around 40 ppb.

$$Normalized\ Bias = 100\left(\frac{1}{N}\right)\sum (O_{lt} - E_{lt}) / O_{lt}$$

Where O_{lt} and E_{lt} are, respectively, the observed and estimated hourly ozone concentration at site l and time t (i.e., matched by time and location) for a particular region and day.

- Normalized Gross Error. This test will compare the difference between all pairs of predictions and observations that are greater than 60 ppb. This is a measure of model precision.

$$Normalized\ Gross\ Error = 100\left(\frac{1}{N}\right)\sum |O_{lt} - E_{lt}| / O_{lt}$$

Assessing Model Performance Statistics

The statistical measures were analyzed with a goal of obtaining the following EPA-defined standards for ozone:

Unpaired highest predictions:	±15-20 percent
Normalized bias:	±5-15 percent
Gross error:	±30-35 percent

Diagnostic and Sensitivity Testing

Diagnostic tests are designed to check the model's formulation and response to various inputs. For a specified change in input condition, the model results are checked to evaluate whether the model response is appropriate. This provides insight into the factors driving model response (e.g., source-receptor relationships, influence of boundary conditions, etc.) that are valuable in understanding and refining model performance, and later on in designing control strategies. Types of diagnostic tests that have often been performed include:

- Alternate boundary and/or initial condition assumptions.
- Emissions perturbations to selected broad source categories (e.g., mobile, area, industrial, biogenic). Perturbations may be simple adjustments or use of alternate assumptions (e.g., use of a different biogenic emissions model).
- Alternate model configurations, e.g.: no PiG treatment; different horizontal advection scheme; different chemical mechanism.

In this study, the term sensitivity test was used to describe an across the board emissions perturbations (e.g., X% VOC or NOx reductions). Sensitivity tests are provide insight into the sources of high ozone in the modeling and therefore are useful for understanding model performance. Sensitivity tests may also provide valuable information to guide the initial design of future year control strategies.

Two tests that have been carried out in some previous studies are (1) zero emissions, and (2) zero boundary and initial conditions. These tests are intended to show how the model responds under two theoretical extreme scenarios: (1) no pollutant emissions within the region, and; (2) no pollutants entering the region from outside. However, neither of these situations can be attained in the real world, and it is often misleading to conduct "physically impossible" tests using a model designed to be physically realistic. The following are alternatives to these two tests which fulfill the same objectives and are also physically reasonable:

- Zero anthropogenic emissions (i.e., only biogenic emissions are included).
- Ultra-clean boundary and initial conditions (i.e., reduce boundary and initial conditions to levels consistent with no anthropogenic emissions in upwind areas).

DEFINITION OF DIAGNOSTIC AND SENSITIVITY TESTS

The final program of diagnostic and sensitivity tests was designed in consultation with the NETAC technical committee.

Diagnostic Tests

1. Zero anthropogenic emissions.

2. Alternate biogenic emissions - reduce biogenic emissions by 30%.

3. Alternate initial and boundary conditions. This was an increase in ozone on northeastern boundary segment from 41 ppb to 60 ppb and an increase initial ozone from 40 ppb to 60 ppb.

4. No plume-in-grid treatment for major NOx point sources.

5. Alternate wind field – modify the base case winds by objective combination of the winds observed at the Longview and Tyler CAMS.

Sensitivity Tests

6. Sensitivity to local emissions reductions (i.e., across the board emission changes for the area *inside* the 4 km grid):
   a) 50 % cut in all anthropogenic emissions.
   b) 50 % cut in all anthropogenic VOC emissions.
   c) 50 % cut in surface anthropogenic NOx emissions.
   d) 50 % cut in elevated point source anthropogenic NOx emissions.

7. Sensitivity to regional emissions reductions (i.e., across the board emission changes for the area *outside* the 4 km grid). Only applies for the RSMs:
   a) 50 % cut in all anthropogenic emissions.

JUNE 1995 DIAGNOSTIC AND SENSITIVITY TESTING

Ozone modeling results are described for the preliminary base year base case and the diagnostic/sensitivity tests. The maximum 1-hour ozone concentrations are reported for three locations (see Figure 5-1 for reference):

1. Gregg county airport monitor (symbol GGGC in Figure 5-1).
2. Tyler monitor (symbol TX47 in Figure 5-1).
3. The location of the maximum modeled 1-hour ozone concentration in the Tyler-Longview-Marshall sub-domain (dashed box in Figure 5-1). This is called the domain-wide maximum ozone. The significance of the domain-wide maximum is that in future year modeling this value will have to be reduced below 125 ppb to show attainment of the 1-hour ozone standard.

Table 5-2 compares the modeled 1-hour ozone maximums to the observed maximum concentrations at the monitoring sites. The domain-wide maximum 1-hour prediction is compared to the highest ozone concentration measured at either monitor. Results are presented for all four days (June 21-23) after the model "spin-up" days (June 18 and 19), however attention should be focused on the results for June 22 and 23 since only these days satisfy the EPA model performance guidelines for 1-hour ozone modeling (see Figure 5-2).

Table 5-3 shows the changes in maximum 1-hour ozone between the sensitivity tests and the base case (i.e., difference = sensitivity – base case). This provides a concise summary of the reductions in peak 1-hour ozone for each sensitivity.

Tables 5-4 and 5-5 show the maximum 8-hour ozone concentrations in the same format as Tables 5-2 and 5-3, respectively.

The model performance statistics summarized in Figure 5-2 were calculated using the standard EPA recommended procedures described above. The bias and gross error were calculated for the sites in East Texas (Longview and Tyler) for all monitored ozone values higher than 60 ppb. In calculating the domain peak accuracy (i.e., unpaired in space or time), only modeled peaks occurring inside the Tyler-Longview-Marshall sub-domain (dashed box in Figure 5-1) were considered.

The results for each model run are discussed below.

Base Case

Ozone levels were under-predicted in the base case on June 20 and 21 and the model performance did not meet EPA guidelines. Results for June 22 and 23 did meet EPA guidelines. One objective of the diagnostic tests discussed below was to identify any justifiable changes in model configuration that would improve overall model performance, especially for June 20 and 21. However, the under-prediction on June 20 and 21 was changed very little by the diagnostic tests. This means that for the future year modeling control strategies should focus on June 22 and 23.

Table 5-2. Summary of maximum 1-hour observed and modeled ozone concentrations (ppb) for June 20-23, 1995.

	Longview Monitor				Tyler Monitor				Domain-wide Max			
	6/20	6/21	6/22	6/23	6/20	6/21	6/22	6/23	6/20	6/21	6/22	6/23
observed	145	108	120	145	109	100	97	96	145	108	120	145
base case	89	95	130	119	111	73	86	89	118	109	142	140
diag1	25	27	23	19	23	23	20	16	29	30	25	22
diag2	83	84	123	116	102	72	86	88	104	98	130	131
diag3	91	97	131	120	113	74	87	89	120	111	143	140
diag4	89	94	133	119	112	73	86	90	119	105	143	138
diag5	104	101	140	134	97	72	76	91	125	108	147	148
sens6a	68	78	96	86	85	55	61	63	96	84	118	105
sens6b	88	93	129	118	109	73	87	89	114	108	142	140
sens6c	79	88	119	104	93	64	70	73	107	106	139	133
sens6d	81	90	109	105	106	67	79	80	114	99	124	115
sens7a	86	92	129	118	109	69	85	88	116	106	142	139

Table 5-3. Summary of changes in maximum 1-hour modeled ozone relative to the base case (ppb) for June 20-23, 1995.

	Longview Monitor				Tyler Monitor				Domain-wide Max			
	6/20	6/21	6/22	6/23	6/20	6/21	6/22	6/23	6/20	6/21	6/22	6/23
diag1	-64	-68	-107	-100	-88	-50	-66	-73	-89	-79	-117	-118
diag2	-6	-11	-7	-3	-9	-1	0	-1	-14	-11	-12	-9
diag3	2	2	1	1	2	1	1	0	2	2	1	0
diag4	0	-1	3	0	1	0	0	1	1	-4	1	-2
diag5	15	6	10	15	-14	-1	-10	2	7	-1	5	8
sens6a	-21	-17	-34	-33	-26	-18	-25	-26	-22	-25	-24	-35
sens6b	-1	-2	-1	-1	-2	0	1	0	-4	-1	0	0
sens6c	-10	-7	-11	-15	-18	-9	-16	-16	-11	-3	-3	-7
sens6d	-8	-5	-21	-14	-5	-6	-7	-9	-4	-10	-18	-25
sens7a	-3	-3	-1	-1	-2	-4	-1	-1	-2	-3	0	-1

Table 5-4. Summary of maximum 8-hour observed and modeled ozone concentrations (ppb) for June 20-23, 1995.

	Longview Monitor				Tyler Monitor				Domain-wide Max			
	6/20	6/21	6/22	6/23	6/20	6/21	6/22	6/23	6/20	6/21	6/22	6/23
observed	110	101	102	103	101	96	94	93	110	101	102	103
base case	78	77	102	103	86	69	76	84	91	95	114	124
diag1	24	26	22	18	22	22	19	15	28	29	24	21
diag2	76	74	96	99	83	68	75	83	87	92	108	116
diag3	80	80	103	104	89	71	77	84	93	97	115	124
diag4	80	78	104	104	87	67	76	85	95	99	119	122
diag5	85	82	109	116	83	70	68	85	98	100	117	129
sens6a	62	63	76	75	67	53	55	60	72	71	85	90
sens6b	77	76	101	102	86	69	76	84	91	94	114	123
sens6c	70	70	93	91	73	61	62	69	86	91	108	116
sens6d	72	72	89	91	82	62	69	76	87	79	94	100
sens7a	73	73	100	101	84	66	74	82	88	92	113	121

Table 5-5. Summary of changes in maximum 8-hour modeled ozone relative to the base case (ppb) for June 20-23, 1995.

	Longview Monitor				Tyler Monitor				Domain-wide Max			
	6/20	6/21	6/22	6/23	6/20	6/21	6/22	6/23	6/20	6/21	6/22	6/23
diag1	-54	-51	-80	-85	-64	-47	-57	-69	-63	-66	-90	-103
diag2	-2	-3	-6	-4	-3	-1	-1	-1	-4	-3	-6	-8
diag3	2	3	1	1	3	2	1	0	2	2	1	0
diag4	2	1	2	1	1	-2	0	1	4	4	5	-2
diag5	7	5	7	13	-3	1	-8	1	7	5	3	5
sens6a	-16	-14	-26	-28	-19	-16	-21	-24	-19	-24	-29	-34
sens6b	-1	-1	-1	-1	0	0	0	0	0	-1	0	-1
sens6c	-8	-7	-9	-12	-13	-8	-14	-15	-5	-4	-6	-8
sens6d	-6	-5	-13	-12	-4	-7	-7	-8	-4	-16	-20	-24
sens7a	-5	-4	-2	-2	-2	-3	-2	-2	-3	-3	-1	-3

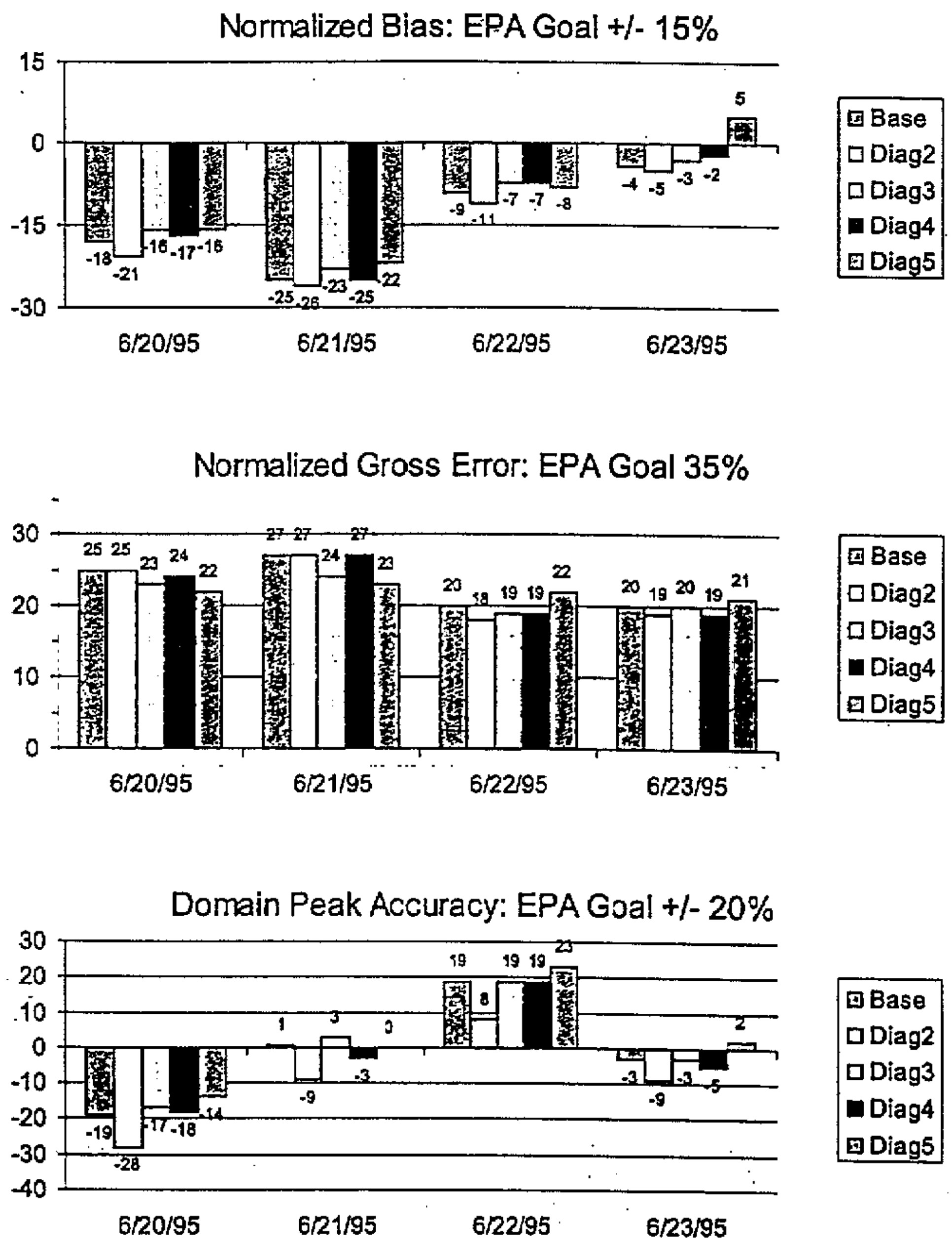


Figure 5-2. Model performance statistics for the June 1995 base case and diagnostic simulations 2 through 5.

Diagnostic Tests

1. Zero anthropogenic emissions. Maximum ozone levels are very low (about 20 – 30 ppb) with no anthropogenic emissions. This means that the modeled ozone levels will be responsive to reductions in anthropogenic emissions.

2. Alternate biogenic emissions. Maximum ozone levels were reduced by 0-14 ppb when biogenic emission levels were reduced by 30%. This means that the modeled ozone levels were somewhat sensitive, but not highly sensitive to the level of biogenic emissions.

3. Increased initial and boundary conditions. Increased ozone on the northeastern boundary segment from 41 ppb to 60 ppb and increased initial ozone from 40 ppb to 60 ppb. This produced only small (0 to 2 ppb) increases in maximum ozone levels showing that the model is unresponsive to changes in the ozone initial and boundary conditions. An important conclusion from this test is that the model under-prediction problems for June 20 and 21 will not be corrected by changing initial and boundary conditions within reasonable bounds.

4. *No plume-in-grid treatment for major NOx point sources. This change impacts the way* NOx emissions from all major point sources in the TLM area are treated in the model. Using the plume-in-grid (PiG) treatment is theoretically an improvement. Turning off PiG produced small changes (-4 to +3 ppb) in maximum ozone levels at the monitoring locations and did not significantly alter model performance.

5. Alternate wind field. The CAMx wind fields were modified by blending the winds from the meteorological model with the observed winds at the Longview and Tyler monitoring sites. This approach changes the winds in the immediate vicinity of the monitors. The objective was to investigate the sensitivity of the ozone modeling results to potential biases in the winds predicted by the meteorological model. While this is a useful diagnostic test, there are theoretical and practical difficulties with blending observations with modeled winds in this way. These difficulties did not appear to be severe in this instance because the differences between the modeled and observed winds were moderate. The result of the diagnostic test was generally an increase in maximum predicted ozone at Longview and a decrease at Tyler. The changes in ozone did not significantly improve model performance on June 20 and 21, but degraded model performance on June 22. Thus, we did not proceed to use these blended winds for further analyses.

Sensitivity Tests

The sensitivity tests all used the same inputs as the base case with the exception of changes to the emissions noted below.

6. Sensitivity to local emissions reductions (i.e., across the board emission changes for the area *inside* the 4 km grid):

    a) 50 % cut in all anthropogenic emissions. Maximum ozone levels were highly responsive (17 to 35 ppb reduction) to this change.

b) 50 % cut in all anthropogenic VOC emissions. Maximum ozone levels were only slightly reduced (0 to 4 ppb reduction) by this change.
c) 50 % cut in surface anthropogenic NOx emissions. Maximum ozone levels were fairly responsive (3 to 18 ppb reduction) to this change.
d) 50 % cut in elevated point source anthropogenic NOx emissions. Maximum ozone levels were fairly responsive (4 to 25 ppb reduction) to this change.

7. Sensitivity to regional emissions reductions (i.e., across the board emission changes for the area *outside* the 4 km grid):

   a) 50 % cut in all anthropogenic emissions. Maximum ozone levels were only slightly reduced (0 to 4 ppb reduction) by this change.

The main conclusions from the sensitivity tests were:

- Ozone levels responded much more to NOx reductions that VOC reductions.

- Ozone levels responded much more to local emission reductions (inside the area of the 4 km grid) than distant emission reductions.

JULY 1997 DIAGNOSTIC AND SENSITIVITY TESTING

The model results (Table 5-6) are compared to the maximum observed concentrations at the respective monitoring sites. The domain-wide maximum prediction is compared to the highest ozone concentration measured at either monitor. Results are presented for all three days (July 16-18) after the model "spin-up" days of July 14 and 15, however attention should be focused on the results for July 16 and 17 since only these days satisfy the EPA model performance guidelines for 1-hour ozone modeling (see Figure 5-3 and discussion below).

Table 5-7 shows the ozone changes between the sensitivity tests and the base case (i.e., difference = sensitivity – base case). This provides a concise summary of the reductions in peak 1-hour ozone for each sensitivity.

Tables 5-8 and 5-9 show the maximum 8-hour ozone concentrations in the same format as Tables 5-6 and 5-7, respectively.

The model performance statistics summarized in Figure 5-3 were calculated using the standard EPA recommended procedures described above. The bias and gross error were calculated for the sites in East Texas (Longview, Tyler and Palestine) for all monitored ozone values higher than 60 ppb. In calculating the domain peak accuracy (i.e., unpaired in space or time), only modeled peaks occurring inside the Tyler-Longview-Marshall sub-domain (dashed box in Figure 5-1) were considered.

Table 5-6. Summary of maximum 1-hour observed and modeled ozone concentrations (ppb) for July 20-23, 1997.

	Longview			Tyler			Domain-wide max		
	7/16	7/17	7/18	7/16	7/17	7/18	7/16	7/17	7/18
observed	139	104	117	n/a	83	91	139	104	117
base case	109	104	75	85	117	74	125	125	110
diag1	39	35	40	38	30	36	40	40	41
diag2	102	100	72	83	113	72	116	118	102
diag3	117	111	92	91	124	88	132	132	123
diag4	111	104	80	85	113	74	124	124	108
diag5	131	117	105	90	133	85	138	146	125
sens6a	88	77	65	65	86	57	106	100	86
sens6b	106	103	75	85	117	74	121	124	109
sens6c	105	95	73	69	107	61	120	118	105
sens6d	95	90	68	81	100	71	121	112	105

Table 5-7. Summary of changes in maximum 1-hour modeled ozone relative to the base case (ppb) for July 20-23, 1997.

	Longview			Tyler			Domain-wide max		
	7/16	7/17	7/18	7/16	7/17	7/18	7/16	7/17	7/18
diag1	-70	-69	-35	-47	-87	-38	-85	-85	-69
diag2	-7	-4	-3	-2	-4	-2	-9	-7	-8
diag3	8	7	17	6	7	14	7	7	13
diag4	2	0	5	0	-4	0	-1	-1	-2
diag5	22	13	30	5	16	11	13	21	15
sens6a	-21	-27	-10	-20	-31	-17	-19	-25	-24
sens6b	-3	-1	0	0	0	0	-4	-1	-1
sens6c	-4	-9	-2	-16	-10	-13	-5	-7	-5
sens6d	-14	-14	-7	-4	-17	-3	-4	-13	-5

Table 5-8. Summary of maximum 8-hour observed and modeled ozone concentrations (ppb) for July 20-23, 1997.

	Longview			Tyler			Domain-wide max		
	7/16	7/17	7/18	7/16	7/17	7/18	7/16	7/17	7/18
observed	88	92	104	n/a	74	86	88	92	104
base case	100	94	70	78	101	68	110	106	98
diag1	37	33	39	36	30	35	39	39	41
diag2	92	91	68	77	96	66	103	99	94
diag3	109	102	85	85	107	83	118	114	109
diag4	102	91	74	79	99	69	109	106	98
diag5	112	103	87	72	112	83	114	119	112
sens6a	83	70	59	61	76	55	91	82	77
sens6b	98	94	70	79	101	68	108	105	98
sens6c	96	85	67	64	90	59	101	95	90
sens6d	89	82	62	76	89	65	102	100	96

Table 5-9. Summary of changes in maximum 8-hour modeled ozone relative to the base case (ppb) for July 20-23, 1997.

	Longview			Tyler			Domain-wide max		
	7/16	7/17	7/18	7/16	7/17	7/18	7/16	7/17	7/18
diag1	-63	-61	-31	-42	-71	-33	-71	-67	-57
diag2	-8	-3	-2	-1	-5	-2	-7	-7	-4
diag3	9	8	15	7	6	15	8	8	11
diag4	2	-3	4	1	-2	1	-1	0	0
diag5	12	9	17	-6	11	15	4	13	14
sens6a	-17	-24	-11	-17	-25	-13	-19	-24	-21
sens6b	-2	0	0	1	0	0	-2	-1	0
sens6c	-4	-9	-3	-14	-11	-9	-9	-11	-8
sens6d	-11	-12	-8	-2	-12	-3	-8	-6	-2

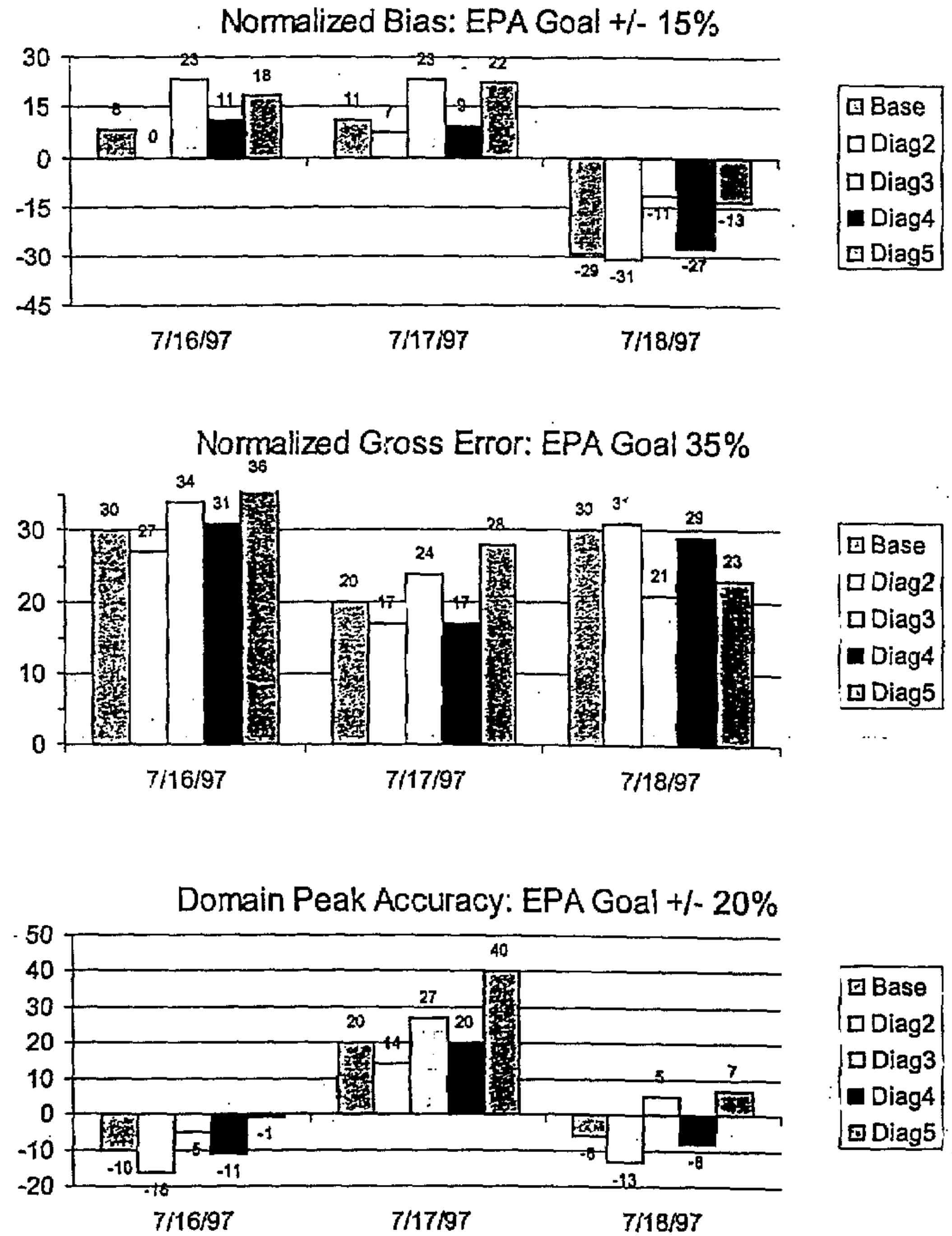


Figure 5-3. Model performance statistics for the July 1997 base case and diagnostic simulations 2 through 5.

The results for each model run are discussed below.

Base Case

In designing the USM there was a concern that the model boundary conditions should be representative of regional ozone levels in East Texas under high ozone conditions. To address this concern, boundary conditions were developed by analyzing regional scale model (RSM) results. These boundary conditions had about 60 ppb of ozone, which is higher than the 41 ppb value being used for RSM boundary conditions. The first model runs for the July 1997 USM clearly showed that 60 ppb was too high for the ozone boundary conditions, and that about 40 ppb would be more appropriate. Therefore, the base case was run using the same boundary conditions as for the RSM i.e., 41 ppb ozone. The effect of assuming higher 60 ppb boundary conditions for ozone is shown in diagnostic test 3, below.

The base case model performance satisfies EPA guidelines on the July 16th and 17th, but not on July 18th. The reason the model performance for the 18th is inadequate is under-prediction of ozone in the afternoon at Longview. This results in a negative overall bias of -29% which falls outside of the acceptable range (+15% to -15%). Model performance at sites other than Longview on July 18th is quite good suggesting that the problem at Longview is quite local in nature - probably related to the characterization of the meteorology. There is a small positive bias on July 16th and 17th (8% and 11%, respectively). The domain-wide peak is slightly under-predicted on the 16th (125 ppb predicted vs. 139 ppb observed) and over-prediction on 17th (125 ppb predicted vs. 104 ppb observed). Overall, the performance for the 16th and 17th is comparable to many previous model applications.

A special study site was operated at Palestine in 1997 as a background site. This provides valuable information for the model performance evaluation of this episode. The time series of ozone at Palestine shows very good base case model performance. The main conclusion from this is that the boundary condition assumptions for the base case are appropriate.

Another source of special data for model performance evaluation of the July 1997 episode was the Baylor aircraft flight through the region at about 2 pm on July 17th. The comparison of base case model results to the Baylor aircraft data is described separately, below.

Based on the model performance evaluation findings, model results for July 16th and 17th are suitable for 1-hour ozone control strategy evaluation.

Diagnostic Tests

1. Zero anthropogenic emissions. Maximum ozone levels with no anthropogenic emissions are about the same as the boundary conditions (about 40 ppb). This means that modeled high ozone levels will be responsive to reductions in anthropogenic emissions.

2. Alternate biogenic emissions. Maximum ozone levels are reduced by 2-9 ppb when biogenic emission levels are reduced by 30%. This has a mixed effect on the model performance statistics: the bias is improved on July 16th and 17th; but the domain-wide peak accuracy is degraded on the 16th but improved on the 17th. Overall, the model performance

is essentially equivalent for the base case and diagnostic test 2. The base case model is not very sensitive to a reduction in biogenic emissions of 30%.

3. Increased initial and boundary conditions. As discussed above, this sensitivity test increased ozone in the initial and boundary conditions from 41 ppb to 60 ppb with associated increases in VOCs and NOx. This produced substantial (6 to 17 ppb) increases in maximum ozone levels showing that the boundary conditions are important. Model performance was significantly degraded relative to the base case.

4. No plume-in-grid treatment for major NOx point sources. This change impacts the way NOx emissions from all major point sources in the TLM area are treated in the model. Using the plume-in-grid (PiG) treatment is theoretically an improvement. Turning of PiG produced small changes (-4 to +5 ppb) in maximum ozone levels at the monitoring locations and did not significantly alter model performance.

5. Alternate wind field. The CAMx wind fields were modified by blending the winds from the meteorological model with the observed winds at the Longview and Tyler monitoring sites. This approach changes the winds in the immediate vicinity of the monitors. The objective was to investigate the sensitivity of the ozone modeling results to potential biases in the winds predicted by the meteorological model. While this is a useful diagnostic test, there are theoretical and practical difficulties with blending observations with modeled winds in this way. These difficulties are quite severe in this instance , and on these grounds alone we recommend not to use this simulation as anything more than a sensitivity test. The result was an increase in maximum predicted ozone at both the Longview and Tyler monitoring locations. These changes in ozone significantly degraded model performance on July 16th and 17th. On July 18th, model performance improved significantly at Longview but was degraded at Tyler. This supports the hypothesis that the model performance problems for Longview on the 18th are related to the meteorology. However, we do not recommend proceeding to use these blended winds for further analyses.

Sensitivity Tests

The sensitivity tests all used the same inputs as the base case with the exception of changes to the emissions noted below.

6. Sensitivity to local emissions reductions (i.e., across the board emission changes for the area *inside* the 4 km grid):

    e) 50 % cut in all anthropogenic emissions. Maximum ozone levels were highly responsive (10 to 31 ppb reduction) to this change.

    f) 50 % cut in all anthropogenic VOC emissions. Maximum ozone levels were only slightly reduced (0 to 4 ppb reduction) by this change.

    g) 50 % cut in surface anthropogenic NOx emissions. Maximum ozone levels were fairly responsive (2 to 16 ppb reduction) to this change.

h) 50 % cut in elevated point source anthropogenic NOx emissions. Maximum ozone levels were fairly responsive (3 to 17 ppb reduction) to this change.

These sensitivity results are very similar to those reported above for the June 1995 RSM. The main conclusions from the sensitivity tests is:

- Ozone levels respond much more to NOx reductions that VOC reductions.

EVALUATION AGAINST AIRCRAFT DATA FOR JULY 17, 1997

The ozone episode period of July 14-18, 1997 is being modeled using the CAMx model. The highest ozone level recorded at a surface monitoring sites during this period was 139 ppb on July 16 at the TNRCC CAMS19 (Gregg County Airport, near Longview). On the next day (July 17) an instrumented aircraft operated for the TNRCC by Baylor University was flown through the East Texas area. This flight recorded ozone concentrations aloft of up to 130 ppb close to the Longview monitoring site. The aircraft also flew through several plumes from industrial sources and urban areas in East Texas. The aircraft data provide an opportunity to evaluate the performance of the CAMx model in simulating ozone and NOy concentrations aloft.

Aircraft Data

Data from the aircraft flight were provided by the TNRCC (personal communication from Brian Lambeth). These data had been quality assured. The data include time and location, altitude, ozone, sulfur dioxide and total oxidized nitrogen (NOy).

The aircraft flight track is shown in Figure 5-4. The location of each data logger entry is marked by a "+" and the time is shown for every twentieth entry. The times shown in Figure 5-4 have the format HHMM, where 1439 is 14 hours and 39 minutes. The altitude, ozone concentration and NOy concentration along the flight track are shown in Figure 5-5. The times shown in Figure 5-5 are in hours (to allow a continuous x-axis scale) so 14.5 means 14 hours and 30 minutes. Note that the aircraft data were recorded in Central Daylight Time, and so all of the times discussed in this memorandum are also CDT. This is different from the procedures used for surface ozone concentrations (CAMS monitors) and for CAMx modeling which always use standard time. The locations of CAMS19, the Texas Eastman chemical plant and three utility sources (TXU Martin Lake, CSW Pirkey and CSW Knox Lee) are also marked on Figure 5-4.

The altitude for most of the flight leg shown in Figure 5-4 was about 2000 feet (see Figure 5-5). There were two main exceptions to this: (1) a spiral from 2000 feet up to 7000 feet and back down to about 2000 feet at about 14:30 (top right in Figure 5-4), and (2) a dip down to about 500 feet at 13:52 as the plane flew over CAMS19.

Model Data

CAMx was configured with 12 layers at fixed heights above ground level as shown in Table 5-10. Layer 7 provides the best match with the aircraft data taken at about 2000 feet. The aircraft data were recorded between 1:45 pm and 3:00 pm whereas CAMx outputs hourly average concentrations. The best match with the aircraft data is provided by the CAMx concentrations for the hour from 2:00 pm to 3:00 pm. For the NOy comparisons, the modeled NOy was calculated as the sum of NO, NO2, PAN, nitric acid and organic nitrates.

Table 5-10. CAMx layer structure for the July 1997 USM.

Layer	Top (m)	Top (ft)
12	3615	11860
11	2640	8661
10	1826	5991
9	1277	4190
8	905	2969
7	642	2106
6	387	1270
5	261	856
4	171	561
3	102	335
2	51	167
1	18	59

Important Limitations to the Comparison between CAMx and Aircraft Data

The concentrations estimated by CAMx represent an average concentration over a one hour period for a grid cell measuring 4000 by 4000 by 255 meters. In contrast, the aircraft data are essentially instantaneous measurements at a point in time and space. This miss-match between the modeled and measured data is unavoidable and it is important to realize that it produces significant limitations on the kind of agreement that can be expected between the modeled and real concentrations. The real atmosphere has considerable variability in winds speeds/directions and pollutant concentrations over scales of a thousand meters and time periods of one hour. Numerical models can not reproduce the stochastic (random) component of these small scale features. In other words, this comparison is much less direct than it may appear to be at first sight, and requires caution in interpreting the results.

Discussion of Comparisons

The modeled and aircraft data are compared in Figures 5-6 and 5-7 for ozone and NOy, respectively. These figures are quite complicated because of the amount of data presented. The landmarks, county boundaries and the flight track are the same as in Figure 5-4. However, the flight track has been modified to show the measured concentrations (ppb) as a number at the data location. To fit these numbers clearly on the chart it is only possible to show every second data logger entry. The modeled concentrations are shown by the isopleths. Remember that model grid size is only 4 km, so the finest scale features that the model can resolve are on the order of 4-8 km (for reference, see the axis scales which are also in km).

The observed locations of plumes with respect to their likely sources indicate that the winds were generally from the east/northeast, and so the aircraft sampled plumes as it flew to the west/southwest of source locations. This can be seen most easily in the flight leg to the west of the Pirkey power plant: the observed ozone increased from about 80 ppb to 95 ppb and then decreased to about 80 ppb as the aircraft flew from north to south. The corresponding NOy change was from about 3 ppb to 17 ppb to 3 ppb. The modeled concentrations are in very good agreement with he observations for both ozone and NOy downwind of Pirkey. The modeled NOy plume is broader than the observed plume because of the 4km grid size of the model.

The aircraft made several loops around the Texas Eastman facility and sampled high ozone (up to 130 ppb) and NOy (up to 17 ppb) to the west-southwest, which are in part attributable to NOx emissions from Texas Eastman. However, the loops to the east of the Eastman plant also sampled ozone over 100 ppb associated with 6-7 ppb of NOy, and these high ozone levels are likely associated with the plume from Pirkey. Thus, the high ozone levels downwind of Eastman (100-130 ppb) represent a bump up due to Eastman emissions overlaid on the impact of Pirkey (90-100 ppb). Ozone levels upwind of Pirkey appear likely to be about 70-80 ppb. The Knox Lee power plant is also close to Eastman and the aircraft flew right overhead of Knox Lee, but there is no clear indication that the aircraft sampled its plume. The modeling indicates some impact immediately downwind of Knox Lee, but smaller than the impact of Eastman or Pirkey. The ozone ranges quoted above should not be over-interpreted, they are only estimates to illustrate the situation that appears to have occurred at this particular time. The aircraft data are not sufficient to quantify separate impacts of Eastman vs. Pirkey vs. Knox Lee emissions.

As just discussed, the aircraft seems to have sampled Pirkey plume just to the east of Eastman at about 14:00. Later on, at 14:48, the aircraft appears to have sampled the Pirkey plume again in a location further to the south. This shift in plume location over 45 minutes illustrates the type of variability in wind directions that occurs in the real atmosphere that can not be captured in modeling.

The aircraft also made a wide loop around the Martin Lake Power plant and then flew right over Martin Lake approaching from the east and departing to the southwest. The modeled winds are from the east for this hour. The aircraft departure leg to the southwest was certainly selected by the pilot to intersect the Martin Lake plume, and the NOy data (Figure 5-7) show that the plume was southwest of Martin Lake at 14:43. A few minutes earlier (14:41) the Martin Lake plume was sampled due south of the power plant. This shows that there was considerable temporal variability in wind direction, and the difference between wind directions near Martin Lake (north to northeast) and near Pirkey and Eastman (east to northeast) indicates that there was also spatial variability. This type of variability is likely due to boundary layer turbulence. The MM5 meteorological model simulation used to drive the CAMx model produces its own turbulence but at horizontal scales determined by the grid resolution.

The aircraft data show 70-80 ppb of ozone upwind of Martin Lake. When the core of the Martin Lake plume was sampled (as indicated by very high NOy of 20-30 ppb), ozone levels were depressed to 40 to 60 ppb. This is consistent with a very young plume with high NOx concentrations that has not yet evolved to the stage where ozone formation has begun. When the aircraft sampled more diluted portions of the Martin Lake plume (5-10 ppb of NOy), ozone levels were 80-95 ppb, or about 10-15 ppb above background. This presents a picture of the Martin Lake plume being shredded into segments in a rather turbulent atmosphere, with the ozone impacts of the NOx emissions depending strongly upon the extent to which the plume has been diluted.

The modeled impacts of the Martin Lake plume are quite different. The plume is very homogenous because the spatial resolution of CAMx (and the underlying model assumptions) prevent the model from resolving the kind of "plume shredding" suggested by the aircraft data. The modeled ozone impact of the Martin Lake emissions is a 30-40 ppb bump up above the upwind levels. This is larger than was observed. However, it is not clear whether agreement would be improved if the Martin Lake plume had been sampled father out from the stack when the plume had dispersed to a more homogenous state that better matches the modeled situation. In other words, *these aircraft data may be too close to the source to allow* the model to do a good job of representing the plume. On the other hand, if the model is over-estimating the rapidity with which the Martin Lake plume forms ozone, and the amount of ozone formed, possible causes include (1) VOC levels that are too high, almost certainly related to the biogenic emission inventory, and (2) overly rapid expansion and dilution of the plume within CAMx. These issues could be investigated by sensitivity simulations such as reducing biogenic emission levels, introducing a very high resolution grid (1 km) just downwind of Martin Lake, or examining the way that the CAMx plume in grid (PiG) module is handling the dispersion and impacts of Martin Lake emissions.

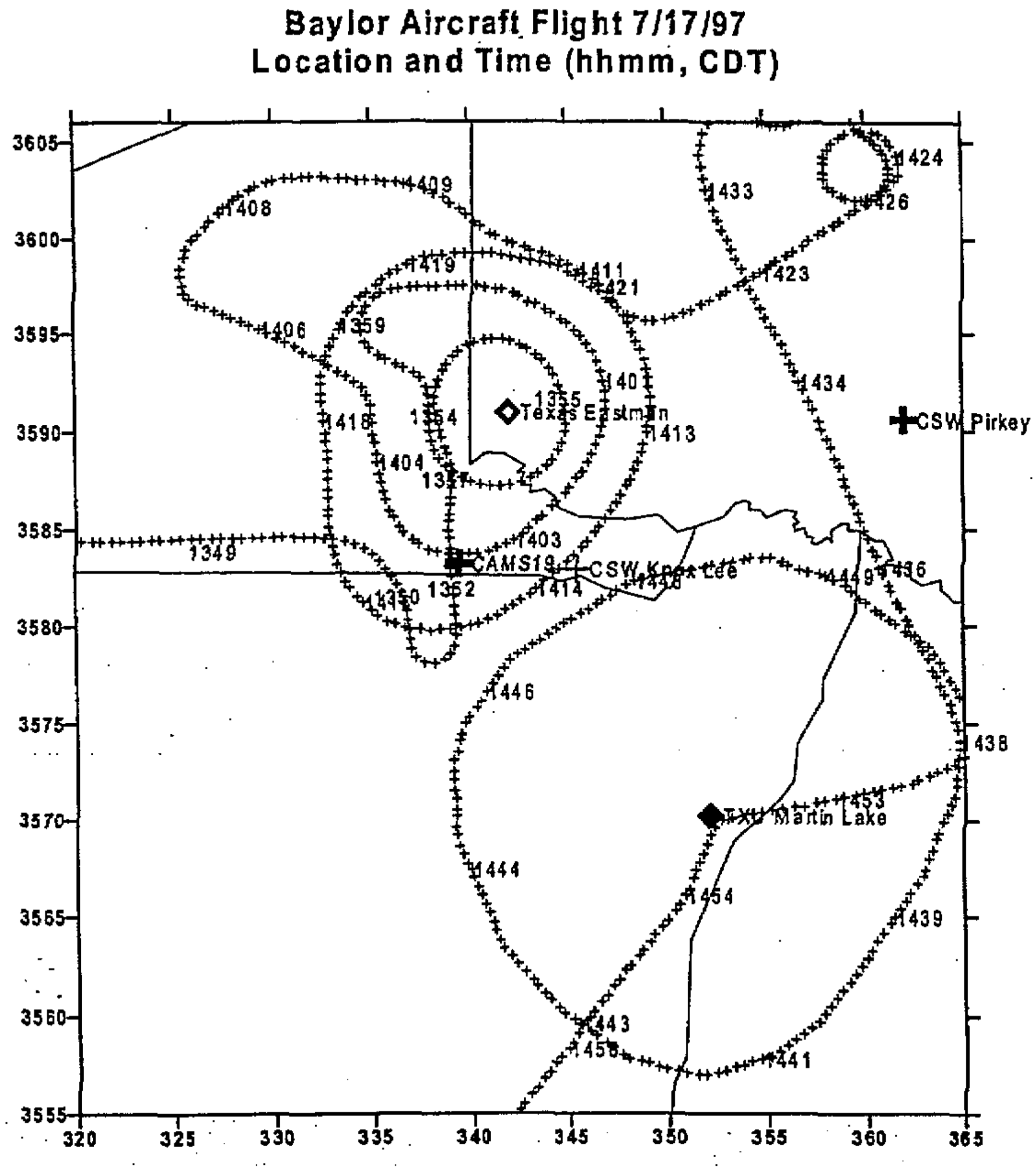


Figure 5-4. The Baylor aircraft flight track through East Texas and key landmarks.

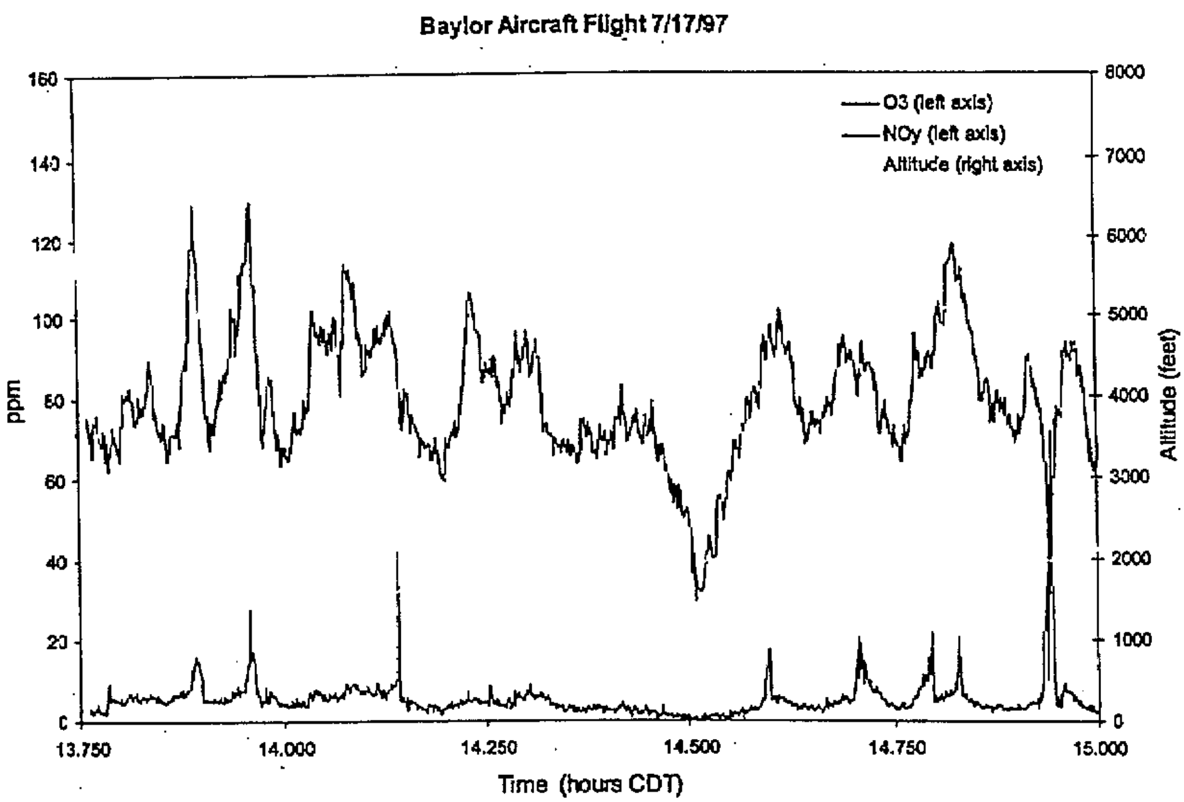
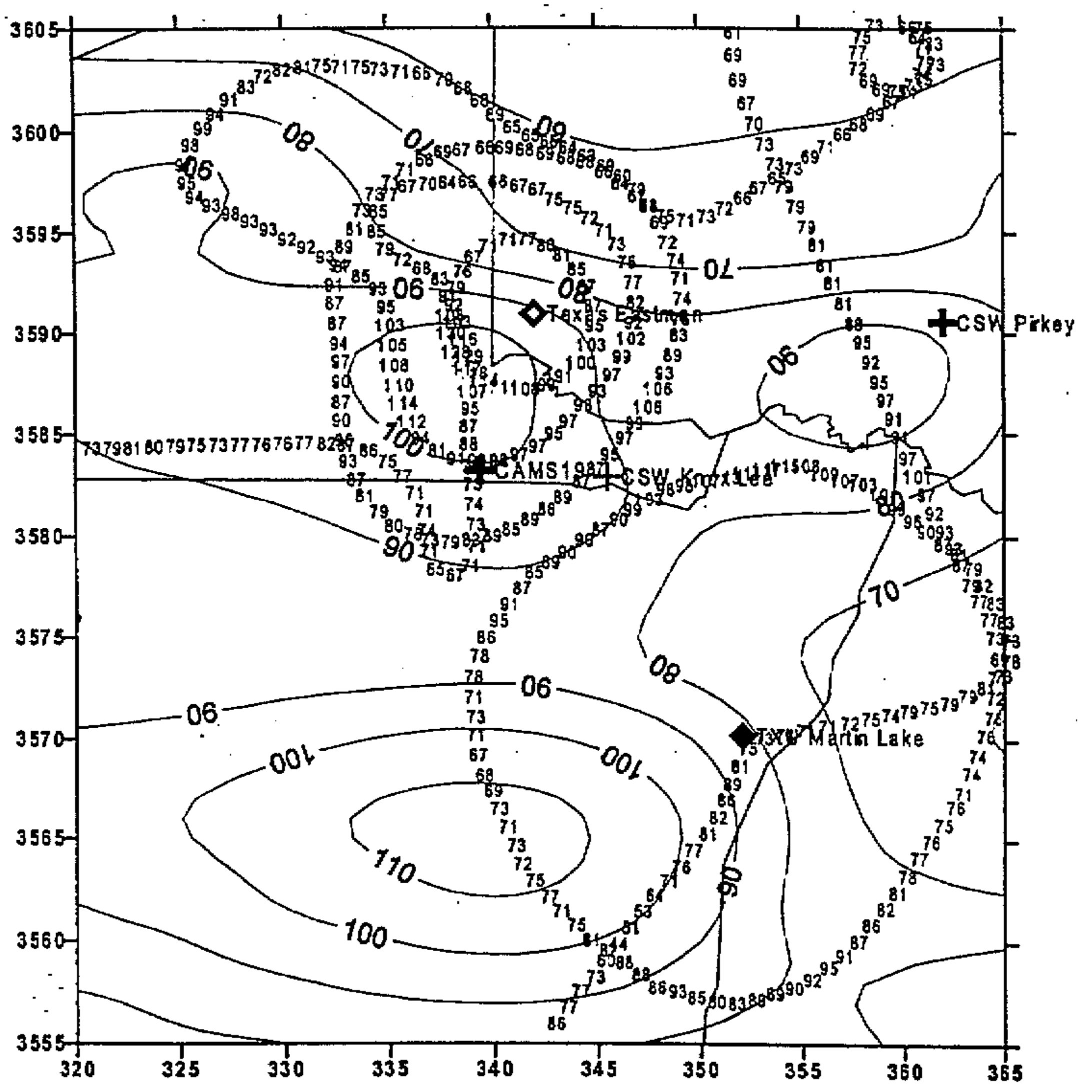


Figure 5-5. Altitude, ozone and NOy along the flight track shown in Figure 5-4.

Baylor Aircraft Flight 7/17/97



Symbols: Observed Ozone (ppb) at about 2000 feet
Contours: CAMx Ozone (ppb) in Layer 7 (Run = Base Case)

Figure 5-6. Comparison of modeled and observed ozone.

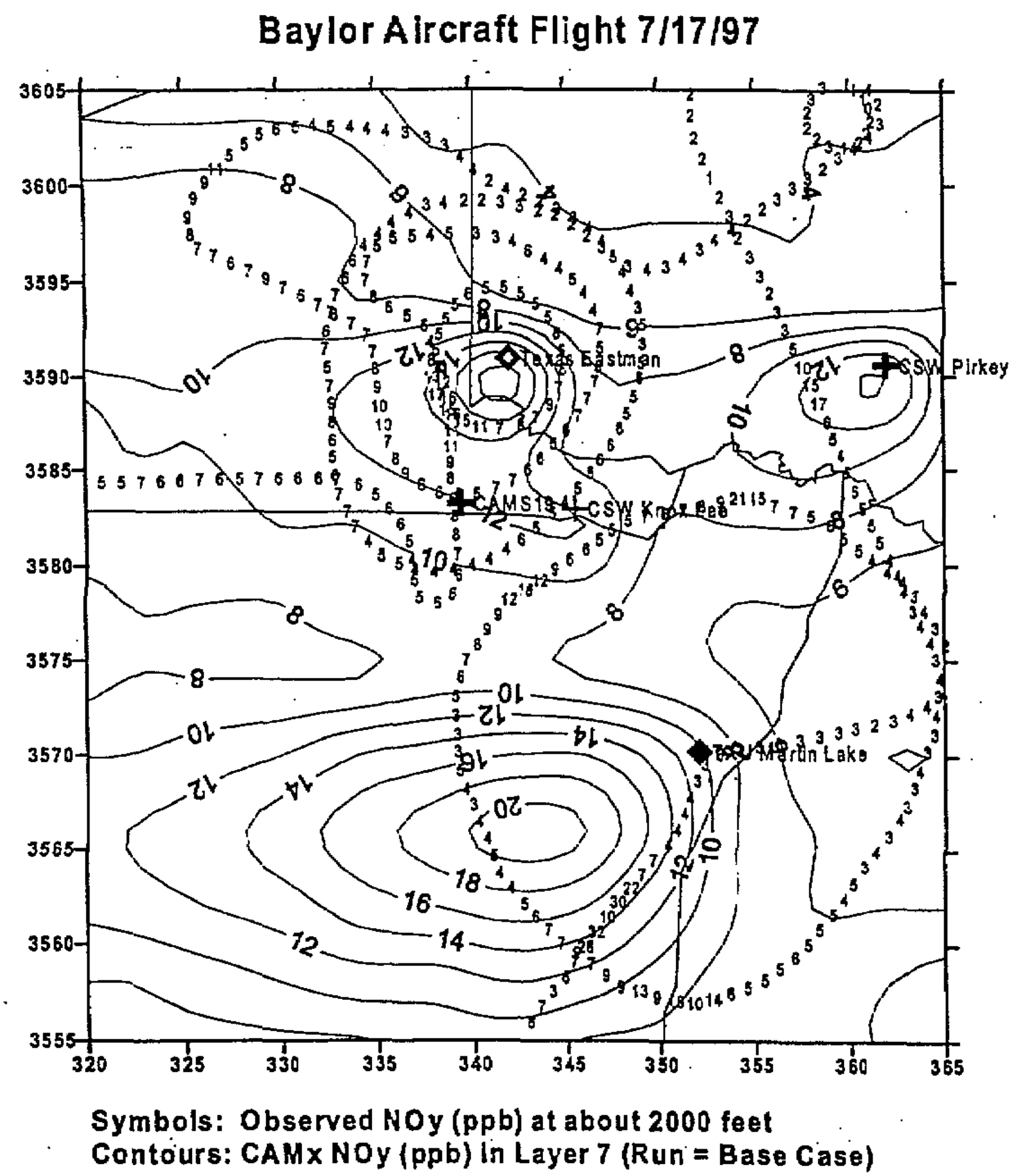


Figure 5-7. Comparison of modeled and observed NOy.

JULY 1995 DIAGNOSTIC AND SENSITIVITY TESTING

Introduction

The preliminary base case developed for the July 1995 episode showed significant model performance problems. The predicted ozone levels reached over 200 ppb which is much higher than any levels ever observed in East Texas. The ozone monitoring network in East Texas is quite limited and so it is likely that ozone reaches higher levels between monitors than are observed at the monitors. However, ozone levels exceeding 200 ppb do not seem credible given that the highest observed values are in the 140-150 ppb range. Based on this finding, an analysis of model performance was undertaken to:

1. Explain why the modeled ozone levels for the preliminary July 1995 base case (base1) are much higher than for the other episodes modeled (June 1995 and July 1997).

2. Develop alternative inputs for key model input parameters so that alternate base cases and diagnostic tests can be considered.

3. Recommend a course of action for proceeding with the July 1995 episode.

Why Are Modeled Ozone Levels so High for the July 7-12, 1995 Episode?

The key meteorological difference between the July 1995 episode and the other two episodes is that the modeled meteorology is more stagnant for July 1995. The meteorological modeling (performed for OTAG using the RAMS model) shows high pressure centered right over East Texas on several episode days. This pattern is consistent with the daily weather maps for this period. The result is very high temperatures, low wind speeds, and limited vertical mixing on several days during the episode. The RAMS wind speeds, wind directions and temperatures agree very well with observations at Longview throughout the episode. We did not have any useful information to evaluate the modeled vertical mixing – the NWS soundings at the Gregg County airport are taken in the morning and evening and so are not useful to evaluate mixing in the critical mid-day period.

To evaluate the vertical mixing we compared the CAMx vertical mixing inputs for the July 1995 episode (based on OTAG RAMS modeling) with those for the June 1995 episode (based on TNRCC modeling with SAIMM). The comparisons are made for the last three days of each episode at the Longview monitoring site. Figures 5-8 and 5-9 show the estimated mixing heights based on SAIMM and RAMS, respectively. In Figure 5-9, base1 is the initial set of CAMx inputs and base2 is an alternate set, described later. The following points are taken from this comparison:

- Note that none of these models (RAMS, SAIMM, CAMx) work in terms of mixing height, instead they use vertical mixing coefficients (Kv) to describe the rate of mixing between model layers. However, it is hard to look at Kvs and interpret the degree of vertical mixing, so we calculated approximate mixing heights from the Kvs. This is useful for interpreting what happens in the models, but remember that the mixing heights are not an exact description of how the models work. The mixing heights are calculated at each hour to the nearest layer interface, hence the step ladder appearance of Figures 5-8 and 5-9.

- The key difference between the SAIMM and RAMS base1 mixing heights is a slower rise in the mixing height in the morning with RAMS. By 11:00, the SAIMM mixing height has reached its maximum diagnosed level of about 1400 meters on all three days, whereas the RAMS base1 mixing height is only about 700 meters. This is a key part of explaining the very high surface ozone levels in July 1995 base case 1.

- Apparently, RAMS predicts deeper mixing in the late afternoon (1800 m) than SAIMM (1400 m). However, this may be partly an artifact of the coarse layer structure in SAIMM above 1400 m so we do not attach much significance to this difference.

- *The evening drop in mixing height occurs about 17:00 with SAIMM but about 19:00 with* RAMS. In the modeling for Dallas/Fort-Worth, TNRCC noted a tendency for SAIMM mixing to shut off abruptly in the late afternoon about two hours early, and Figures 5-8 and 5-9 are consistent with this. However, this does not appear to have resulted in model performance problems for the SAIMM based simulations for East Texas.

In technical terms, RAMS is clearly a superior model to SAIMM. However, when RAMS was run for OTAG, information on vertical mixing was not archived from the RAMS *simulation making it necessary to reconstruct the Kvs from other parameters that were saved.* This is an extra source of uncertainty in the vertical mixing coefficients from the OTAG RAMS run. An alternate set of CAMx vertical mixing inputs (base2) is developed below.

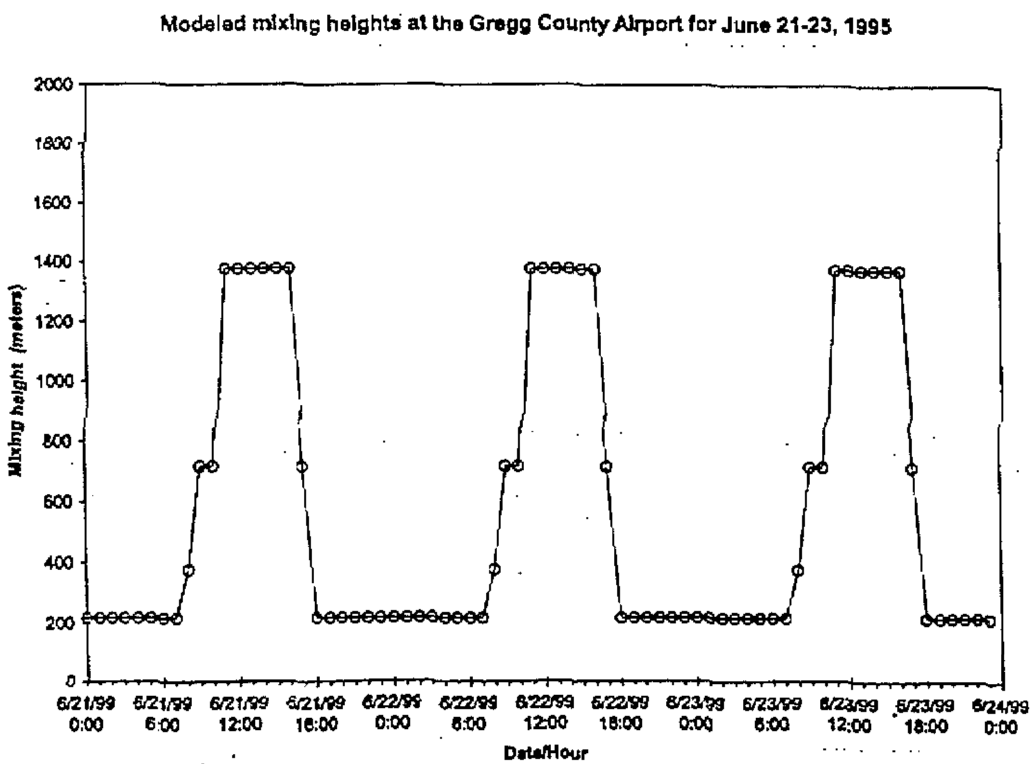


Figure 5-8. Modeled mixing heights based on SAIMM at Longview for June 21-23, 1995.

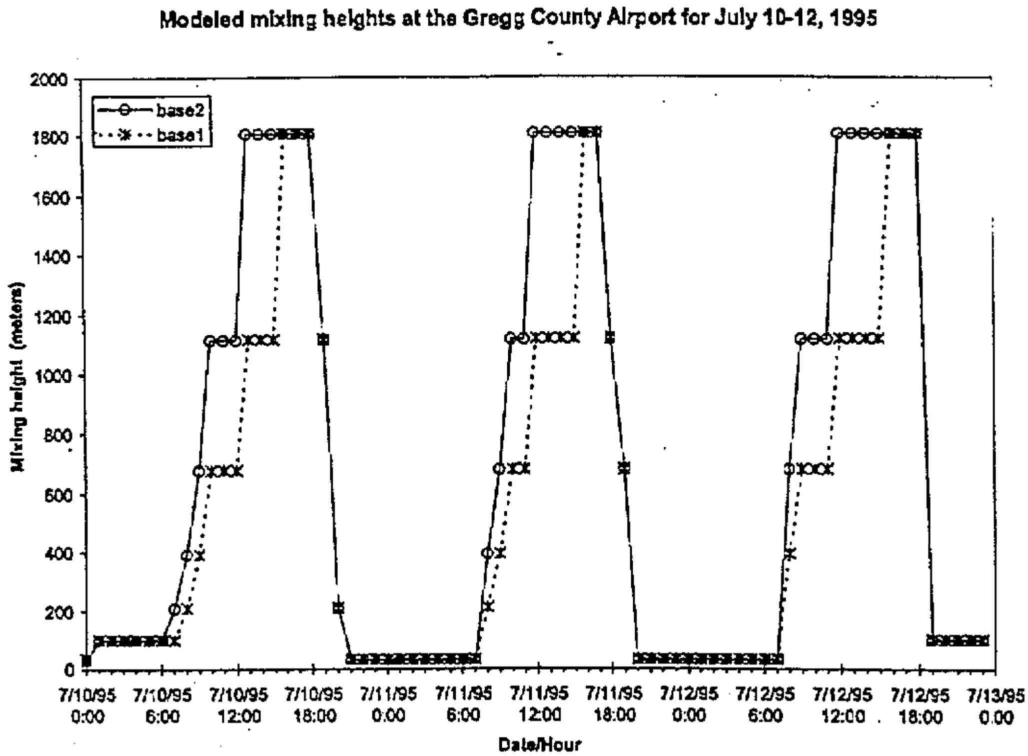


Figure 5-9. Modeled mixing heights based on RAMS at Longview for July 10-12, 1995 for Base Case 1 and Base Case 2.

We believe that uncertainties in vertical mixing are an important part of the model performance problems for this episode, but we should not neglect other potential factors. The high ozone levels result from interactions between VOC and NOx emissions. In several cases, the simulations show that the unreasonably high predicted ozone levels are associated with NOx emissions from point sources. The NOx emissions from these sources are probably the most certain part of the emission inventory because these sources were equipped with continuous emission monitors (CEMS) and we used the hourly CEM data in our emission inventory. The VOCs that are interacting with this NOx in the model to form high ozone are dominated by biogenic emissions. Thus, we should consider the possibility that the excessive ozone levels are indicative of too much biogenic emissions.

NETAC put resources into improving the biogenic emissions by improving the characterization of the biomass density distribution (i.e., where the trees are, what type they are, how much biomass they have), but there are uncertainties in other aspects of the biogenic emission inventory (e.g., emission factors, emission factor models, characterization of solar radiation). This was recognized in choosing diagnostic simulations with 30% lower biogenic emissions for the other two episodes – simulations which showed relatively minor reductions in modeled ozone levels and no significant degradation (or improvement) in model performance relative to the base cases. Considering these results, there may be some technical basis for conducting modeling with 30% lower biogenic emissions. The discussion below considers changes to these two model inputs (vertical mixing and biogenic emissions).

Alternate Base Case Inputs and Diagnostic Test Results

Based on the analyses described above two factors were considered in developing alternate base cases for the July 1995 episode: (1) vertical mixing and (2) biogenic emission levels. This does not rule out contributions from other factors to the model performance problems.

Alternate Vertical Mixing Inputs

The apparent problem with the vertical mixing (Kv) inputs described above is slow growth of the mixing height in the morning. Alternate Kv inputs were developed (Base Case 2) using the procedure described below:

1. Diagnose the depth of the mixed layer in the base case1 Kv fields to find the highest CAMx layer that is well-mixed with the layers below it.
2. Between 07:00 and 16:00, increase the depth of the well-mixed layer by one CAMx layer.
3. To generate the corresponding Kv inputs needed for input to CAMx, calculate Kvs for this mixed layer using an O'Brien profile.
4. For all other times and layers, use the same Kvs as base case 1.

The mixing heights diagnosed from these base case 2 Kvs are shown in Figure 5-9 alongside the base case1 mixing heights. The effect of increasing the mixing height by one CAMx layer after 07:00 is to accelerate the growth of the mixing height in the morning. Stopping the adjustment at 16:00 prevents the mixed layer growing any deeper than in base1. Thus, this approach has produced the desired change in the vertical mixing.

Simulations Conducted

In addition to the preliminary base case (base1), we conducted a series of diagnostic simulations with alternate assumptions for vertical mixing:

Base2 – Revised base case with accelerated vertical mixing.

Diag1 – Base2 with zero anthropogenic emissions.

Diag2 – Base 2 with biogenic emissions reduced by 30%.

Diag4 – Base 2 with no plume-in-grid treatment for major NOx point sources.

Diag5 – Base2 with alternate wind fields by blending the modeled winds with observed winds at the Longview and Tyler CAMS.

Diagnostic simulations 1, 2, 4 and 5 are the same as were performed for the other episodes. This includes a simulation with 30% reduced biogenic emissions in (Diag2). An additional simulation was also performed with a deeper cut to biogenic emissions:

Diag7 – Base 2 with biogenic emissions reduced by 50%.

The results of these simulations were compared and key summaries are included here. The maximum observed and predicted ozone levels at the Longview and Tyler monitors and for the Eat Texas sub-domain are shown in Table 5-11. The EPA model performance statistics are compared in Figure 5-10. Table 5-11 and Figure 5-10 focus on the last three episode days (July 10-12) because these had high observed ozone and are after the CAMx spin up days (July 7-9).

Table 5-11. Summary of maximum 1-hour observed and modeled ozone concentrations (ppb) for July 10-12, 1995.

	Longview			Tyler			East Texas sub-domain peak		
	7/10	7/11	7/12	7/10	7/11	7/12	7/10	7/11	7/12
observed	85	123	111	78	85	90	85	123	111
base1	89	157	166	63	127	88	131	226	189
base2	82	126	136	61	113	86	108	182	156
diag1	26	19	19	27	19	16	29	24	23
diag2	78	120	127	59	110	85	103	162	145
diag4	82	129	137	61	112	86	111	183	152
diag5	78	129	143	61	115	110	108	184	172
diag7	74	114	115	58	105	83	98	145	134

The conclusions from each simulation may be summarized as follows:

Base Case1 – Maximum ozone levels are unreasonably high ozone on 7/11 and 7/12.

Base Case 2 – Maximum ozone levels are reduced relative to base1. The reductions in ozone levels at the Longview and Tyler monitors are sufficient for the EPA bias and gross error statistics to fall within acceptable ranges on 7/10 through 7/12. The peak ozone in the East Texas sub-domain is still much higher than observed on 7/11 (182 ppb compared to 123 ppb) and 7/12 (156 ppb compared to 111 ppb) so that the domain peak accuracy statistic is well outside the EPA performance goal.

Diag1 – Zero anthropogenic emissions. Maximum ozone levels with no anthropogenic emissions are very low, as expected. This means that modeled high ozone are related to anthropogenic emissions.

Diag2 – 30% reduction in biogenic emissions. Maximum ozone levels are reduced by up to 20 ppb such that the highest predicted value is 162 ppb on 7/11. This improves all statistical measures of model performance (relative to base2) on 7/11 and 7/12, however the domain peak accuracy statistic is still outside the EPA performance goal of 20% on 7/11 (32%) and 7/12 (31%).

Diag4 – No plume-in-grid treatment for major NOx point sources. This has little impact on model performance relative to base2.

Diag5 - Alternate wind field. The CAMx wind fields were modified by blending the winds from the meteorological model with the observed winds at the Longview and Tyler monitoring sites. This approach changes the winds in the immediate vicinity of the monitors. The objective was to investigate the sensitivity of the ozone modeling results to potential biases in the winds predicted by the meteorological model. While this is a useful diagnostic test, there are theoretical and practical difficulties with blending observations with modeled winds in this way. These difficulties should not be severe in this instance because the modeled winds are in relatively good agreement with the observations. However, this change increases maximum predicted ozone at both the Longview and Tyler monitoring locations which degrades the model performance statistics. Thus, there is no reason to pursue this sensitivity approach further.

Diag7 - 50% reduction in biogenic emissions. Maximum ozone levels are reduced by up to 37 ppb such that the highest predicted value is 145 ppb on 7/11. This improves all statistical measures of model performance (relative to base2) on 7/11 and 7/12 and the domain peak accuracy statistic is comparable to the EPA performance goal of 20% on 7/11 (18%) and 7/12 (21%). The bias and gross error statistics for 7/11 and 7/12 are very good indicating that the model is doing a good job of replication the observed ozone at these locations. This diagnostic simulation meets the statistical performance goals on 7/11 and 7/12 - however, NETAC did not conclude that this argument is sufficient to justify adopting diagnostic simulation 7 as the base case, as discussed below.

Four more figures are included below to provide additional details on the predicted ozone levels for selected cases. Figures 5-11 through 5-13 show the peak 1-hour ozone isopleth plots for July 11 for the base2, diag2 and diag7 simulations. This shows the effect of progressively reducing biogenic emissions on the day with the highest ozone levels. Notice that the greatest reductions in ozone occur at the "hot spots" with very high ozone. Figure 5-14 compares the time series predictions of ozone for base2 and diag7 to the observed values at monitor locations. This figure shows that both base2 and diag7 performing very well in predicting ozone at the monitors, hence the good bias and gross error statistics. The model performance problems for this episode really are focused on the prediction of very high ozone in localized plumes that generally miss the sparse monitoring network.

Based on the results of the diagnostic tests and performance evaluations performed for the July 1995 episode, the NETAC technical committee decided not to proceed further with this episode. The TNRCC and EPA modeling representatives to NETAC concurred with this decision. However, based on the sensitivity of the model performance problems to the level of biogenic emissions, it was decided to perform an evaluation of modeled biogenic isoprene levels against the 1998 isoprene data collected at Longview, as described below.

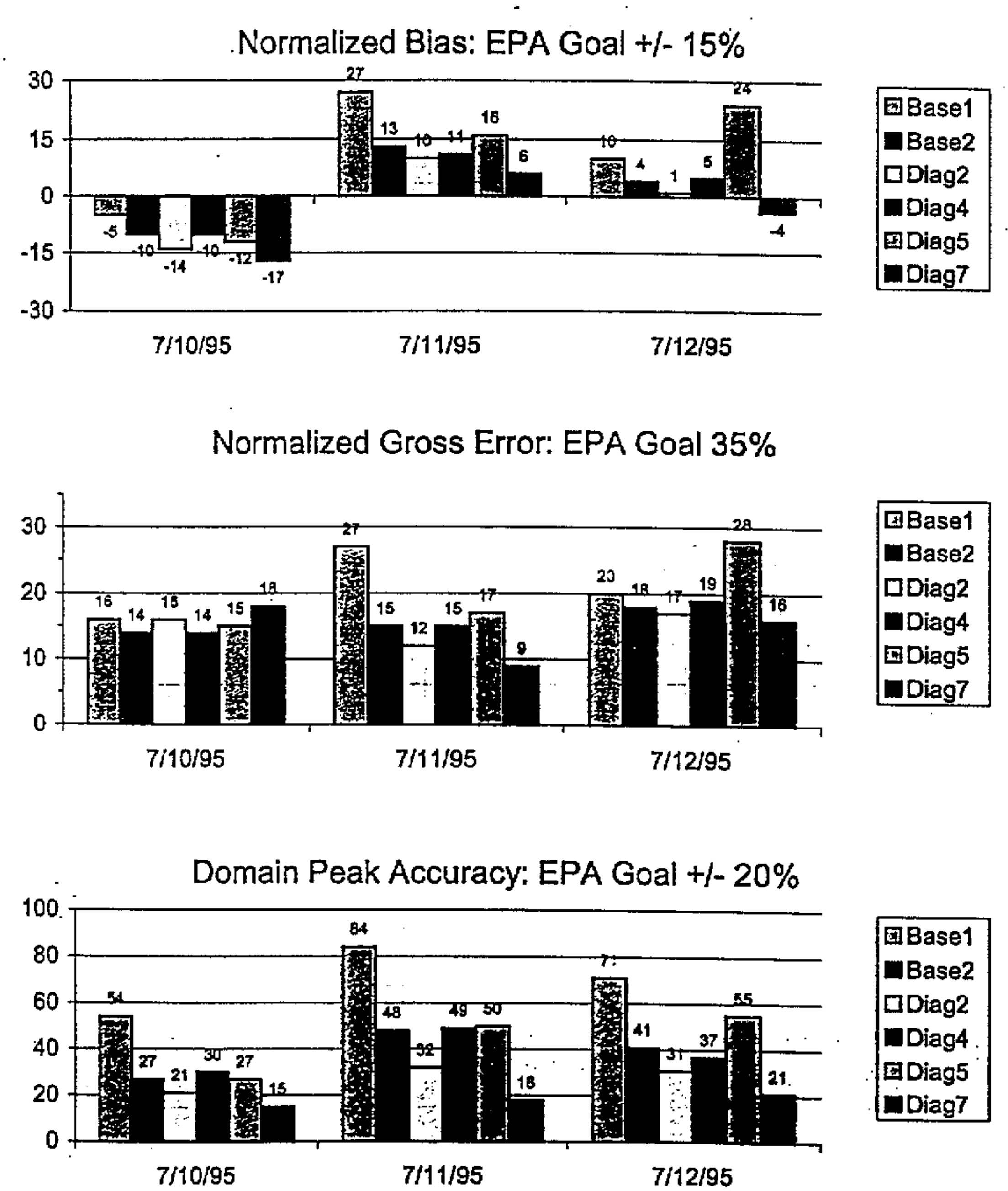
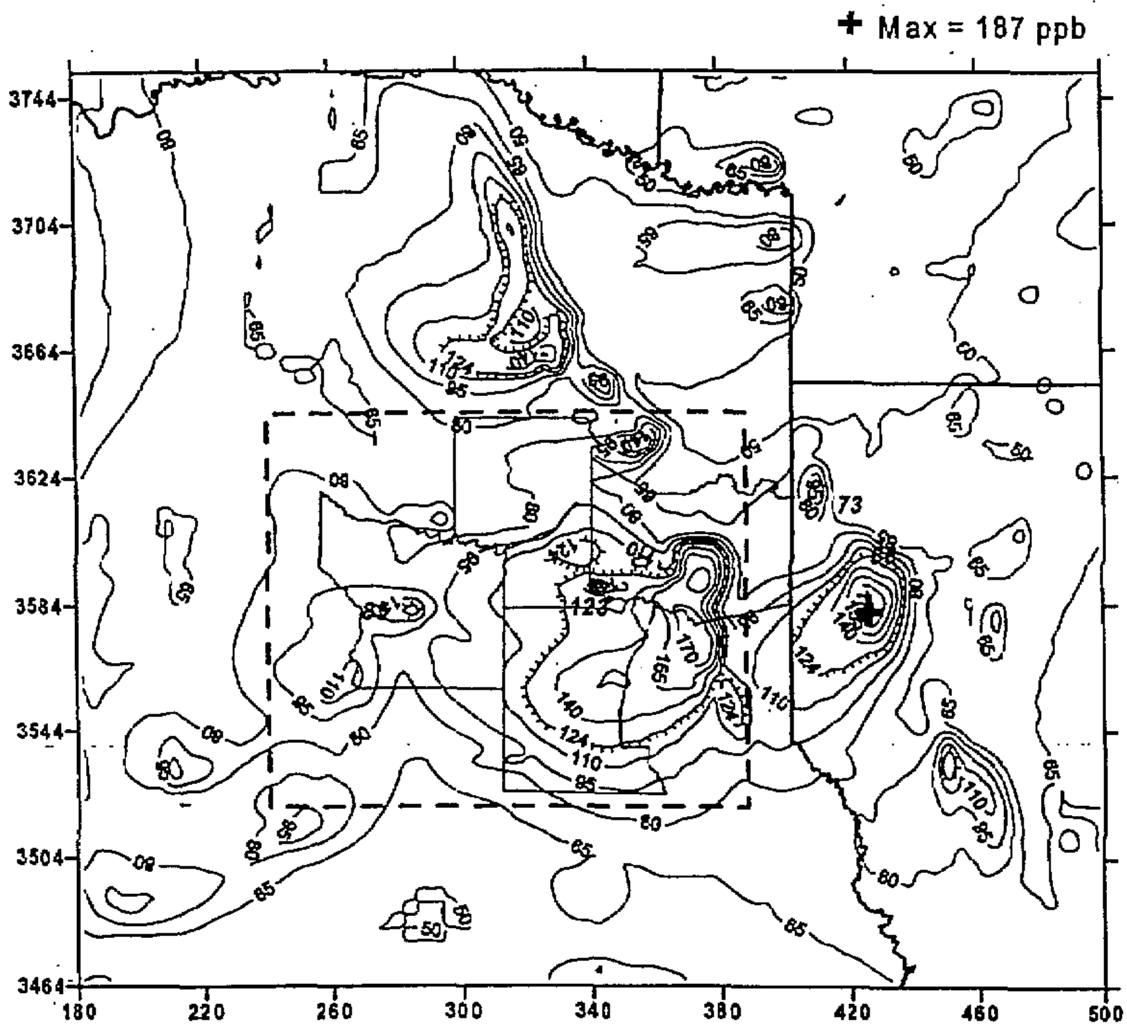


Figure 5-10. Summary of statistical model performance measures.



Daily Max 1-Hour Ozone (ppb)
Run = base2: July 1995 Base Case 2
July 11, 1995

Figure 5-11. Daily maximum 1-hour ozone fo0r Base Case 2 on July 11, 1995.

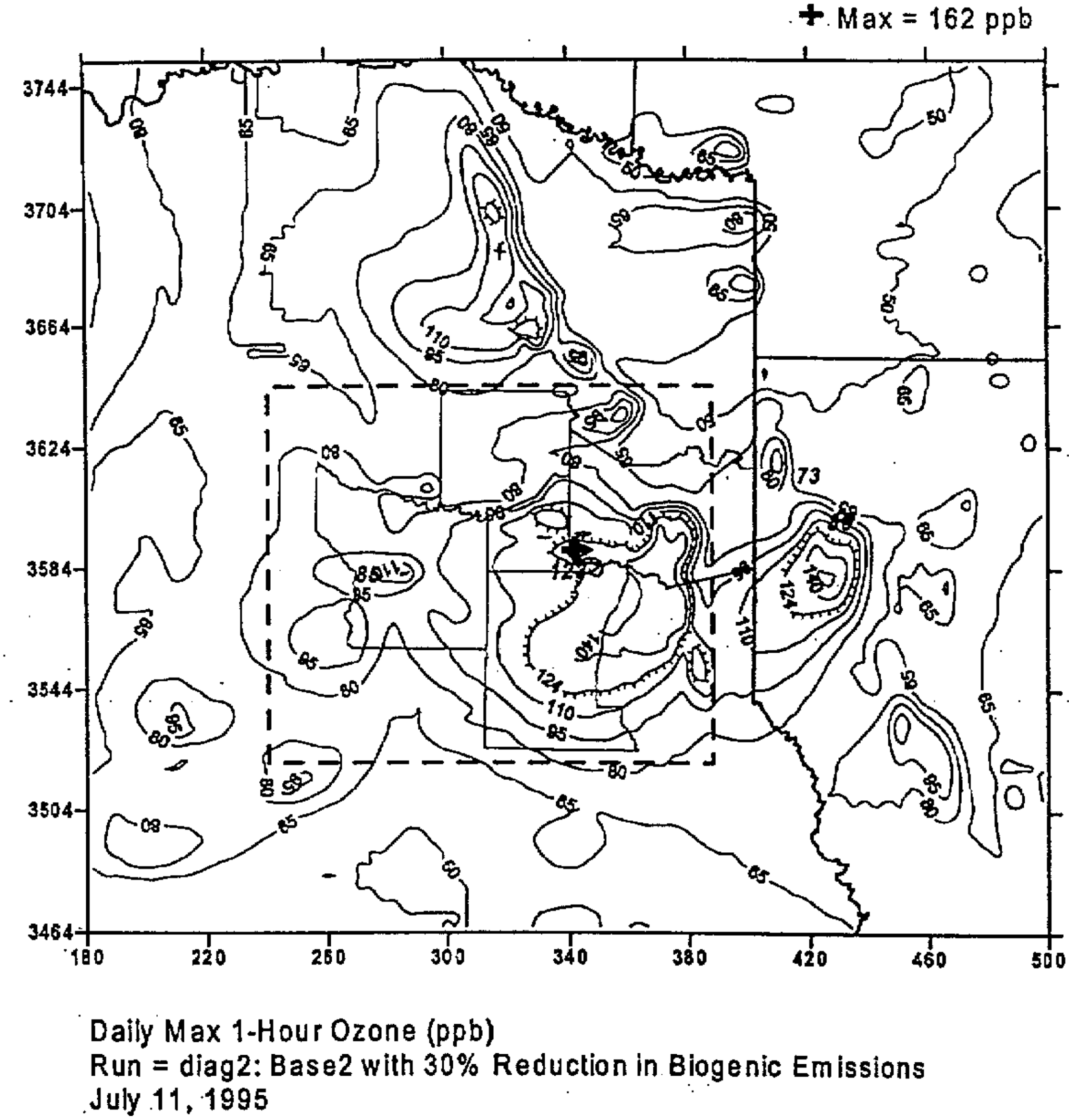


Figure 5-12. Daily maximum 1-hour ozone for Diag2 on July 11, 1995.

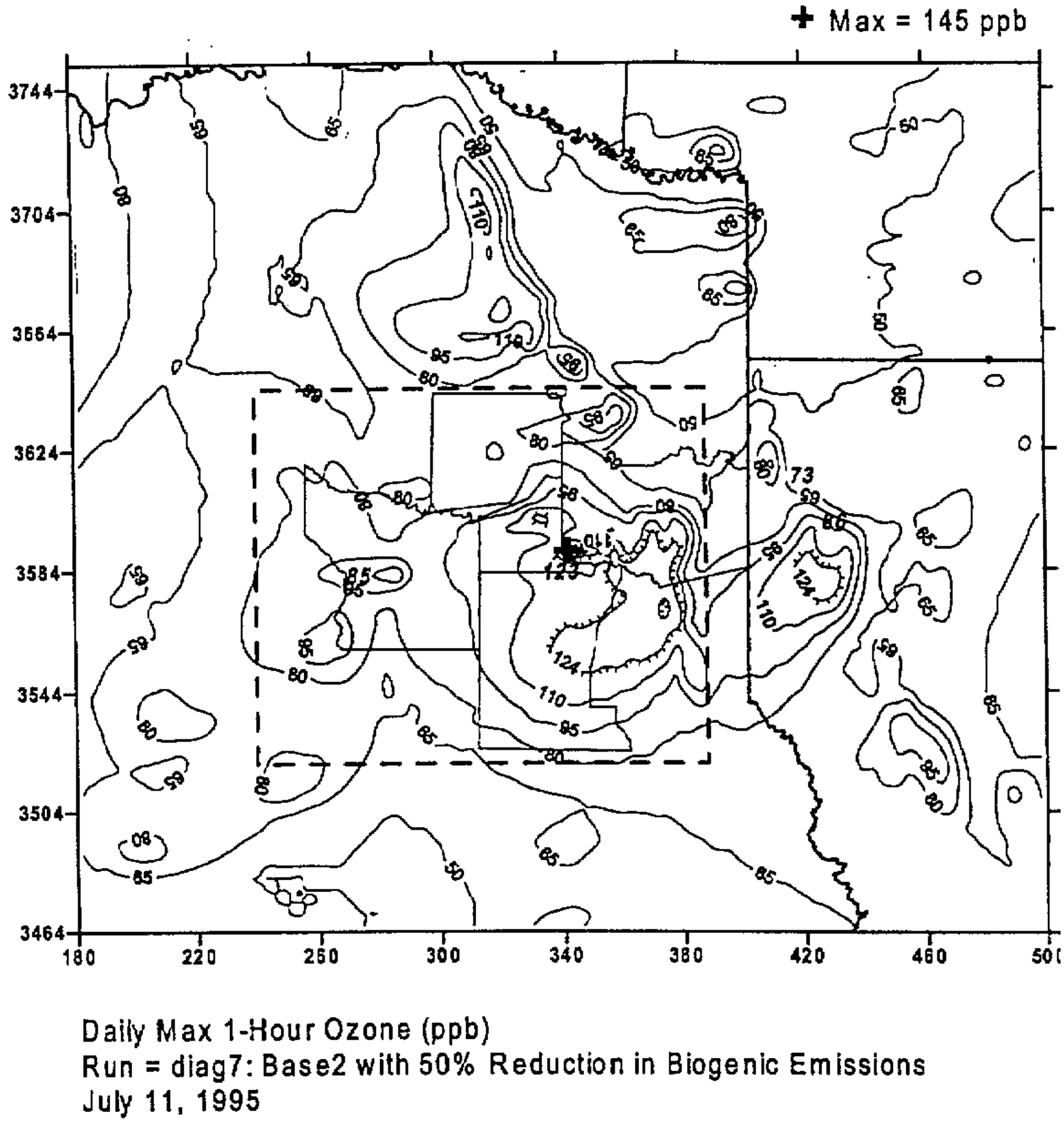


Figure 5-13. Daily maximum 1-hour ozone for Diag7 on July 11, 1995.

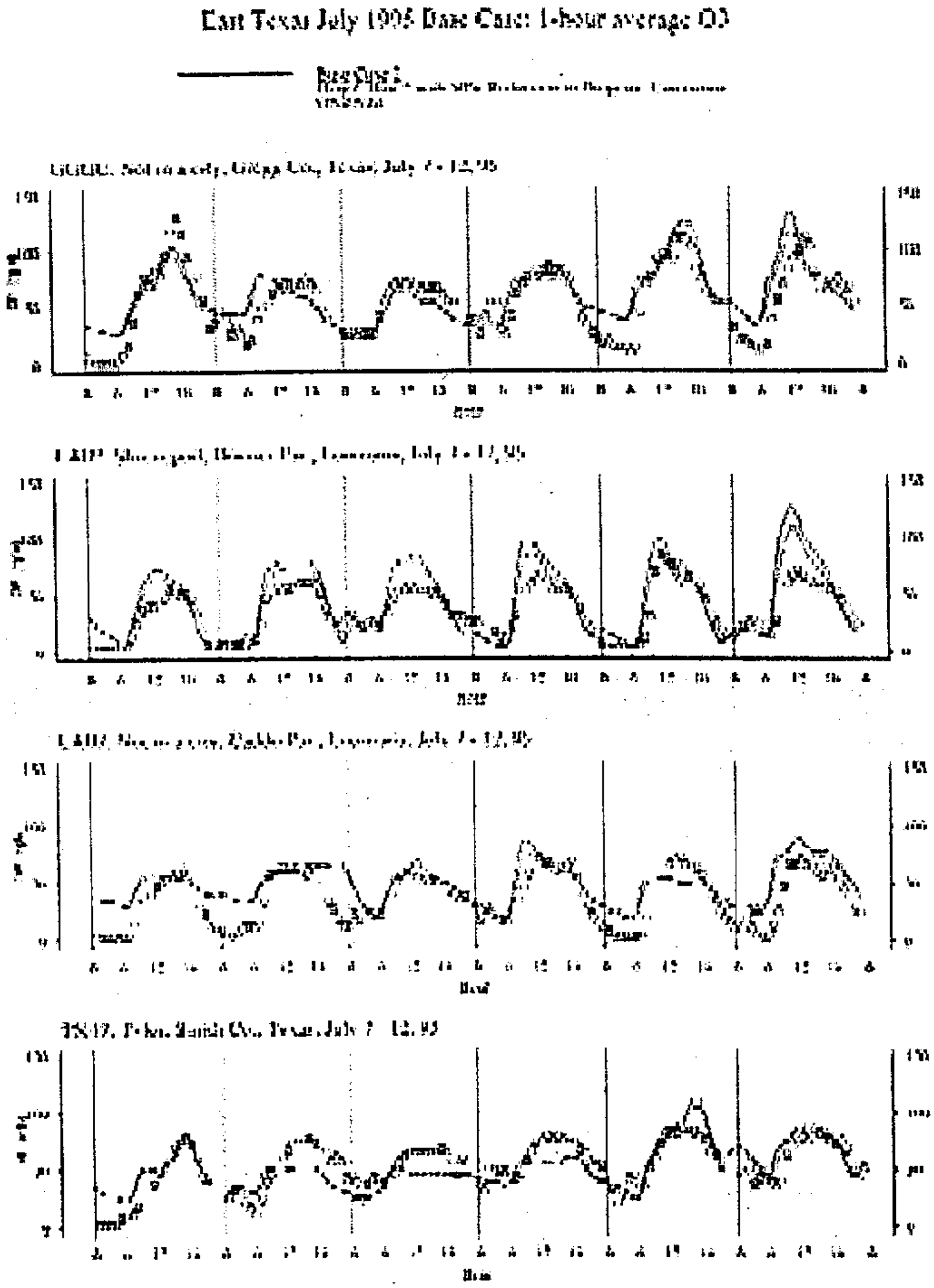


Figure 5-14. Time series of 1-hour ozone at monitoring locations for base2 and diag7.

ISOPRENE EVALUATION FOR LONGVIEW

The model performance evaluation and diagnostic testing for the July 1995 episode raised concern that the biogenic emissions might be overestimated. The most straightforward approach to evaluating the biogenic emission inventory would be to compare the levels of biogenic hydrocarbons (specifically, isoprene) in the modeling to ambient measurements for the same time periods. Unfortunately, there was no ambient sampling for hydrocabons in the 4 km domain during the 1995/97 episode periods.

An extensive set of hydrocarbon data was obtained for the CAMS19 site near Longview in 1998. Therefore, it was decided to compare the modeled isoprene concentrations for the June 1995 and July 1997 episodes to the 1998 measurements at Longview. The July 1995 episode was excluded from this comparison because of concern that uncertainties in the characterization of vertical mixing (described above) might bias the comparison. The comparison focused on isoprene because this is the dominant biogenic hydrocarbon in the emissions inventory and the ambient data, because isoprene is highly reactive toward ozone formation, and because isoprene is tracked explicitly in the CB4 chemical mechanism used in CAMx allowing an unambiguous comparison.

Isoprene Observations

In the summer of 1998, VOC canister samples were collected at CAMS19 as part of this study. The sampling is described in the report prepared for NETAC by Dr. David Allen of the University of Texas at Austin (UT, 1998). Briefly, there were 92 samples of which 85 were 1-hour integrated samples collected at Longview (CAMS19) and 7 were grab samples collected in surrounding forests. The CAMS19 samples were collected on ozone action days throughout the summer, between 23 June and 19 September, 1998.

Isoprene Predictions

The isoprene predictions were the surface layer model predictions for the CAMS19 site from the preliminary base case model runs for June 1995 and July 1997. This means that the biogenic emission inventory was based on version 1 of GLOBEIS (see section 4) which uses the emission factor algorithms from BEIS2 with local biomass density data based on surveys and GIS analysis. The emissions estimates are transformed to atmospheric concentrations by the photochemical model (CAMx) which accounts for the effects of atmospheric dispersion and chemical reaction. Isoprene predictions were available for 10 episode days in 1995 and 1997

Comparison

The predicted and observed isoprene concentrations are compared in Figure 5-15. The comparison was made by aggregating data over all available days to how to a single diurnal profile. The mean diurnal profiles are shown by the lines and symbols. The bars show the range of variability at each hour (assuming there is more than 1 data point) by showing the spread between the 25th and 75th percentiles of the data.

The diurnal patterns are similar for the observations and predictions with concentration peaks occurring near sunrise and sunset. This is a common feature of both predicted and observed isoprene diurnal profiles and it arises because of weaker dispersion at sunrise and sunset which allows isoprene to build up near the ground. To compare the magnitude of predicted and actual isoprene emissions it is best to focus on the middle of the day when the atmosphere is well-mixed and isoprene emission rates are high. The predicted values exceed observed by roughly factor of five in the middle of the day. This strongly suggests that the predicted isoprene emission rates are over-estimated, however we do not attach too much significance to the exact level of over-prediction (five) because of uncertainties in the comparison.

One potentially important uncertainty in the comparison is temperature. Isoprene emission rates generally increase strongly with temperature (unless plants are drought stressed, or temperatures are exceptionally high) so if the modeled days were systematically hotter than the days on which the ambient samples were collected, this could bias the comparison. To check for this possibility, the daily maximum temperatures (for Shreveport, nearby) are compared in Figure 5-16 over all the modeled days and all the days when observations were collected. This comparison shows that the modeled days tended to be cooler than the observed days, so this factor does not account for the modeled isoprene concentrations being higher than observed.

Apples and Oranges?

The comparison of predicted and observed isoprene data is difficult to interpret because of miss-matches in the data being compared. Most importantly, the data are from different years: 1998 vs 1995/97. The predicted values are from the spatial interpolation of four 4 km grid squares for a surface layer that is 20 m deep, whereas the observations are essentially for a single location (CAMS19). The comparison has been made for only a single site which is located in the middle of a wide expanse of grass at an airfield. For these reasons, caution is warranted and the findings should not be over-interpreted. However, other studies have also found a tendency for the current biogenic emissions models to over-estimate isoprene emissions. Fore example, an evaluation of the OTAG July 1995 modeling for Eastern U.S. compared data for 15 sites across Eastern U.S. and found a tendency to over-predict isoprene, as described at "http://capita.wustl.edu/OTAG/Reports/morris/EXECSUM.html."

Effect on Isoprene of Reducing Biogenic Emission Levels

Diagnostic simulations were performed with biogenic emissions reduced by 30% (simulations diag2 for the June 1995 and July 1997 episodes, discussed above). Comparison of the predicted isoprene levels at Longview in the diag2 simulations to the preliminary base cases showed that reducing isoprene emission levels by 30% resulted in a 40% decrease in modeled surface concentrations. This non-linear response is consistent with the model chemistry. Isoprene levels in the base cases are sufficiently high so as to suppress OH radical concentrations extending the lifetime of isoprene. When isoprene emissions are reduced, the lifetime of isoprene is also reduced, producing a greater than expected reduction in the surface concentration.

Conclusion

This evaluation strongly suggests that the predicted isoprene emission rates are over-estimated, however we do not attach too much significance to the exact level of over-prediction (five) because of uncertainties in the comparison. Similar tendencies to over-predict biogenic emissions have been seen in other recent studies.

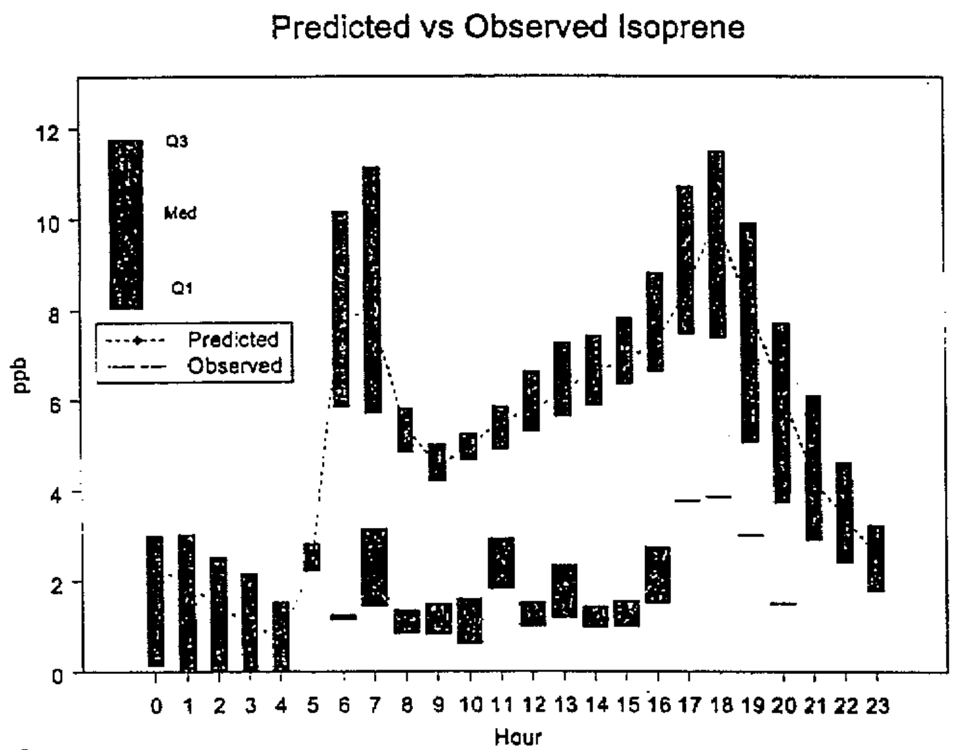
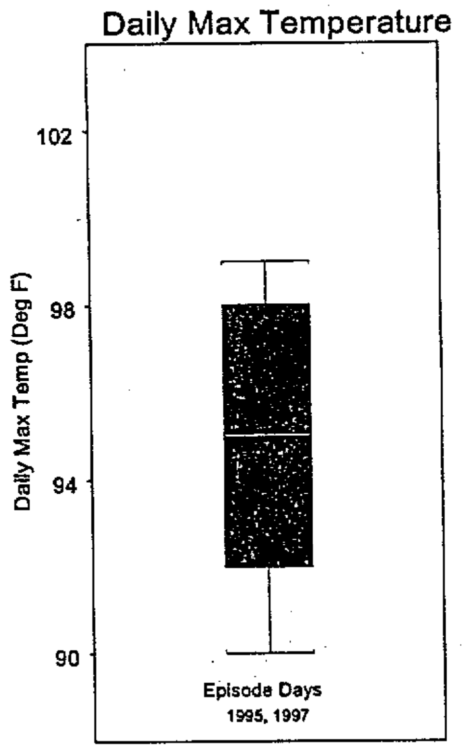


Figure 5-15. Comparison of observed and predicted isoprene concentrations for the CAMS19 site near Longview.



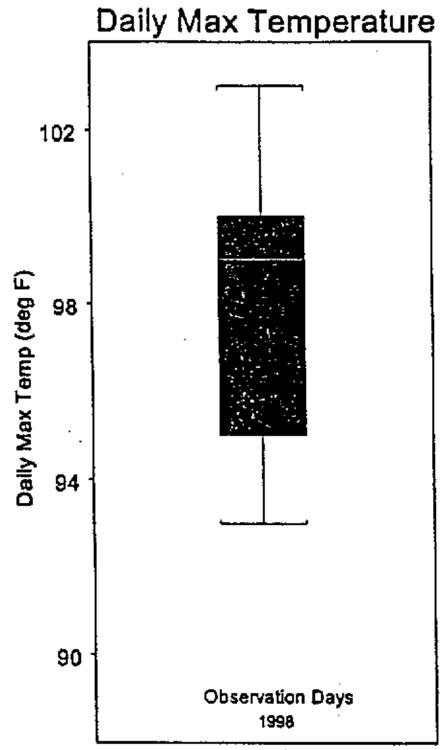


Figure 5-16. Comparison of observed and predicted isoprene concentrations for the CAMS19 site near Longview.

FINAL BASE CASE (BASE2)

The evaluation of the biogenic emission inventory, described above, suggested that biogenic emissions were over-estimated. In addition, diagnostic tests for the June 1995 and July 1997 episodes showed that ozone model performance was not significantly different when biogenic emissions were reduced. Therefore, the NETAC technical committee (with the concurrence of TNRCC and EPA modeling representatives) decided to reduce the level of biogenic emissions in the final base case simulations. Reductions of 30 and 50 percent were evaluated, as described below, leading to the conclusion that a 30 percent reduction was most appropriate. Subsequent to this decision, a new version of the biogenic emissions model (GLOBEIS2, as described in section 4) became available which predicted biogenic emissions to be about 30 percent lower than in the previous inventory. *The final base case simulations (base2) for June* 1995 and July 1997 use biogenic emissions from GLOBEIS2. A final base case was not developed for the July 1995 episode because it had been decided not to proceed with this episode, as discussed above.

Evaluation of 30% and 50% Reductions to Biogenic Emissions

The statistical model performance for ozone is compared between the preliminary base case (base1) and base1 with biogenic emissions reduced by 30 and 50 percent in Figures 5-17 and 5-18. As noted previously, model performance is not significantly improved or degraded when biogenic emissions are reduced 30 percent, looking over the four modeling days as a group. A 50% reduction in biogenic emissions significantly degrades base case model performance. The most significant problem is that with a 50% reduction in biogenic emissions, the "Domain Peak Accuracy" drops to -21% on July 16 which eliminates this day and reduces the number of days with "acceptable" model performance from four to three. The peak 1-hour ozone concentrations at the Longview and Tyler monitors and for the East Texas sub-domain are compared in Tables 5-12 and 5-13. Note that with 50% reduced biogenic emissions, the peak ozone values are less than 125 ppb on all days, which means that this scenario shows modeled attainment of the ozone standard for the base years. For these reasons, a 50% reduction in biogenic emissions is an acceptable base case in combination with the other base case model inputs (meteorology, etc.).

Table 5-12. *Peak 1-hour ozone for the June 1995 preliminary base case (base1), base1 with* biogenic emissions reduced by 30 and 50 percent, and the final base case (base2).

	Longview		**Tyler**		**Sub-Domain Maximum**	
	6/22/95	**6/23/95**	**6/22/95**	**6/23/95**	**6/22/95**	**6/23/95**
Base 1	130	119	86	89	142	140
30% Reduction	123	116	86	88	130	131
50% Reduction	116	110	83	86	121	122
Base 2	119	117	84	88	127	134

Table 5-13. Peak 1-hour ozone for the July 1997 preliminary base case (base1), base1 with biogenic emissions reduced by 30 and 50 percent, and the final base case (base2).

	Longview		**Tyler**		**Sub-Domain Maximum**	
	7/16/97	**7/17/97**	**7/16/97**	**7/17/97**	**7/16/97**	**7/17/97**
Base 1	109	104	85	117	125	125
30% Reduction	102	100	83	113	116	118
50% Reduction	96	96	81	107	109	111
Base 2	107	103	84	115	120	122

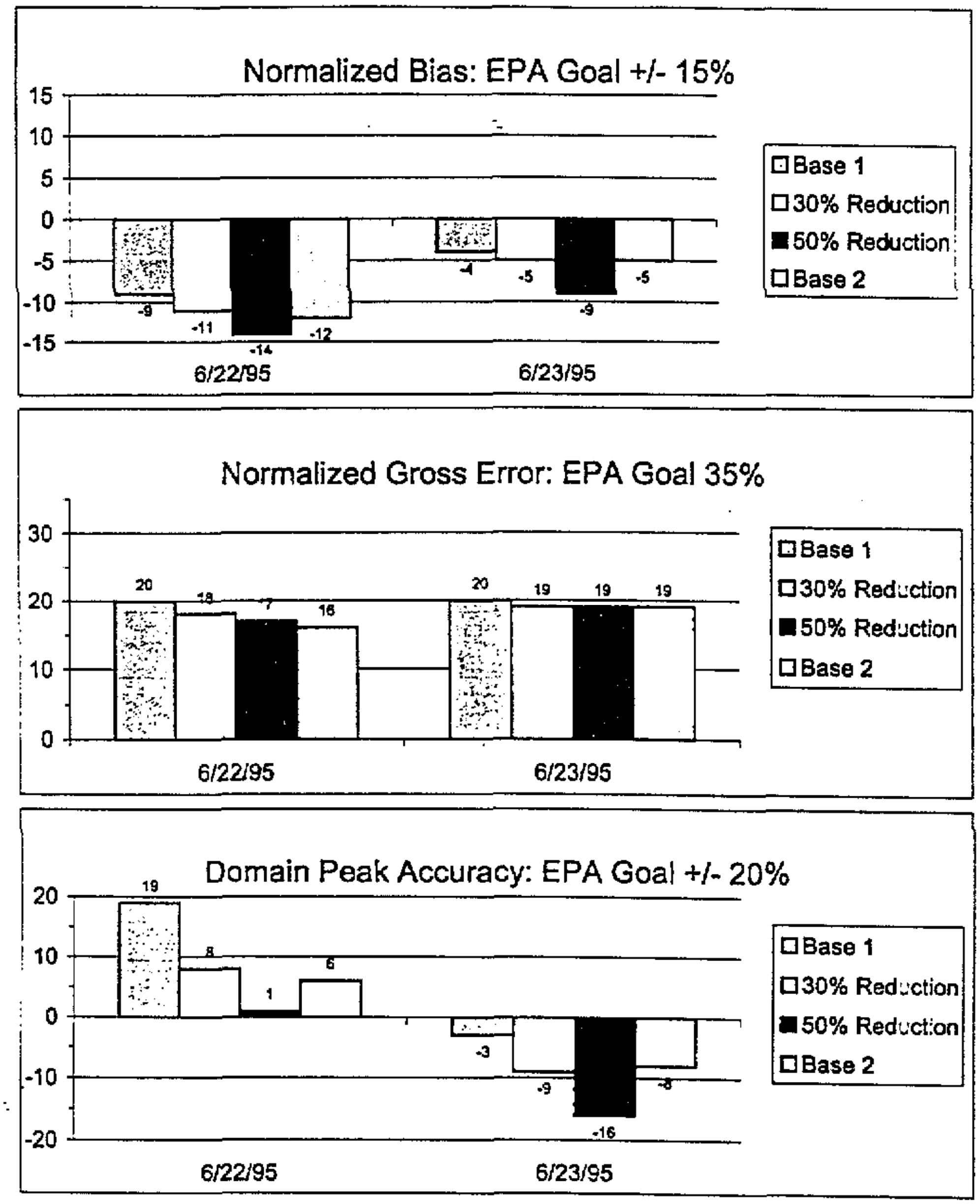


Figure 5-17. Comparison of EPA model performance measures for the June 1995 preliminary base case (base1), base1 with biogenic emissions reduced by 30 and 50 percent, and the final base case (base2).

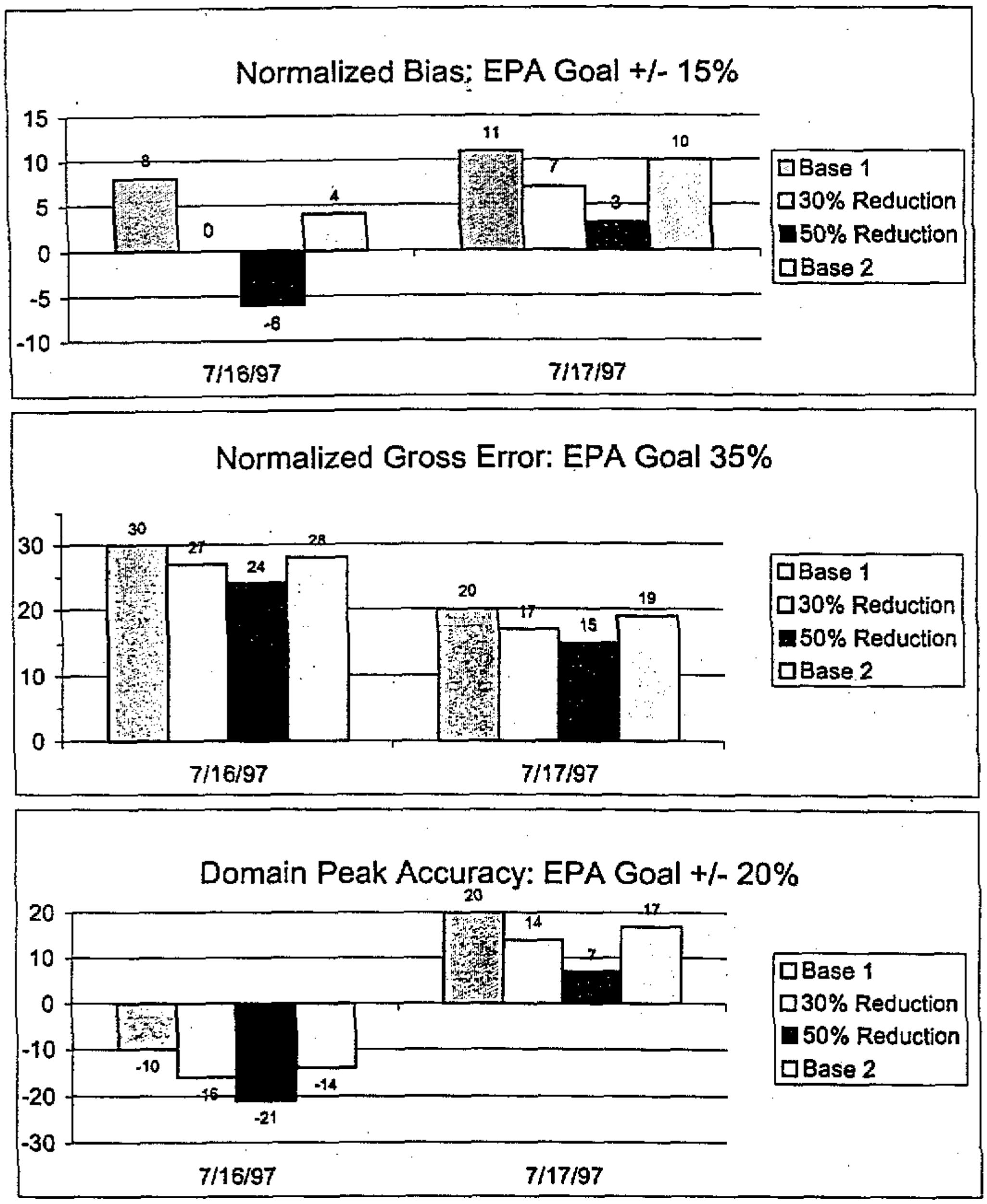


Figure 5-18. Comparison of EPA model performance measures for the July 1997 preliminary base case (base1), base1 with biogenic emissions reduced by 30 and 50 percent, and the final base case (base2).

Model Performance with GLOBEIS2 Biogenic Emissions

Model performance statistics were re-calculated for the revised base year base case with Globeis2 biogenic emissions (Base2). These statistical measures are compared in Figures 5-17 and 5-18 to the preliminary base case, and base1 with 30% reduced biogenic emissions (a 50% reduction in biogenic emissions is not an acceptable base case). These comparisons show some day-to-day differences for specific model performance measures, but overall model performance is similar for base1, base1 with 30% reduced biogenics and base2. The conclusion is that all three scenarios are equally valid based on the model performance for ozone. However, base2 is the preferred scenario because it has reduced biogenic emission levels which are more consistent with the ambient isoprene data for Longview and because it is based on the most up-to-date biogenic emissions model. The base2 scenarios were selected as the final base case.

Isopleth and Time Series Plots for Base Case 2

Isopleth plots of daily maximum 1-hour ozone are shown in Figures 5-19 through 5-25 for the June 1995 and July 1997 base case 2 scenarios. The observed daily maximum 1-hour ozone values measured at each monitoring site are also shown as numbers at the site location (site locations were shown in Figure 5-1). Time series plots comparing the predicted and observed 1-hour ozone concentrations are shown in Figures 5-26 and 5-27.

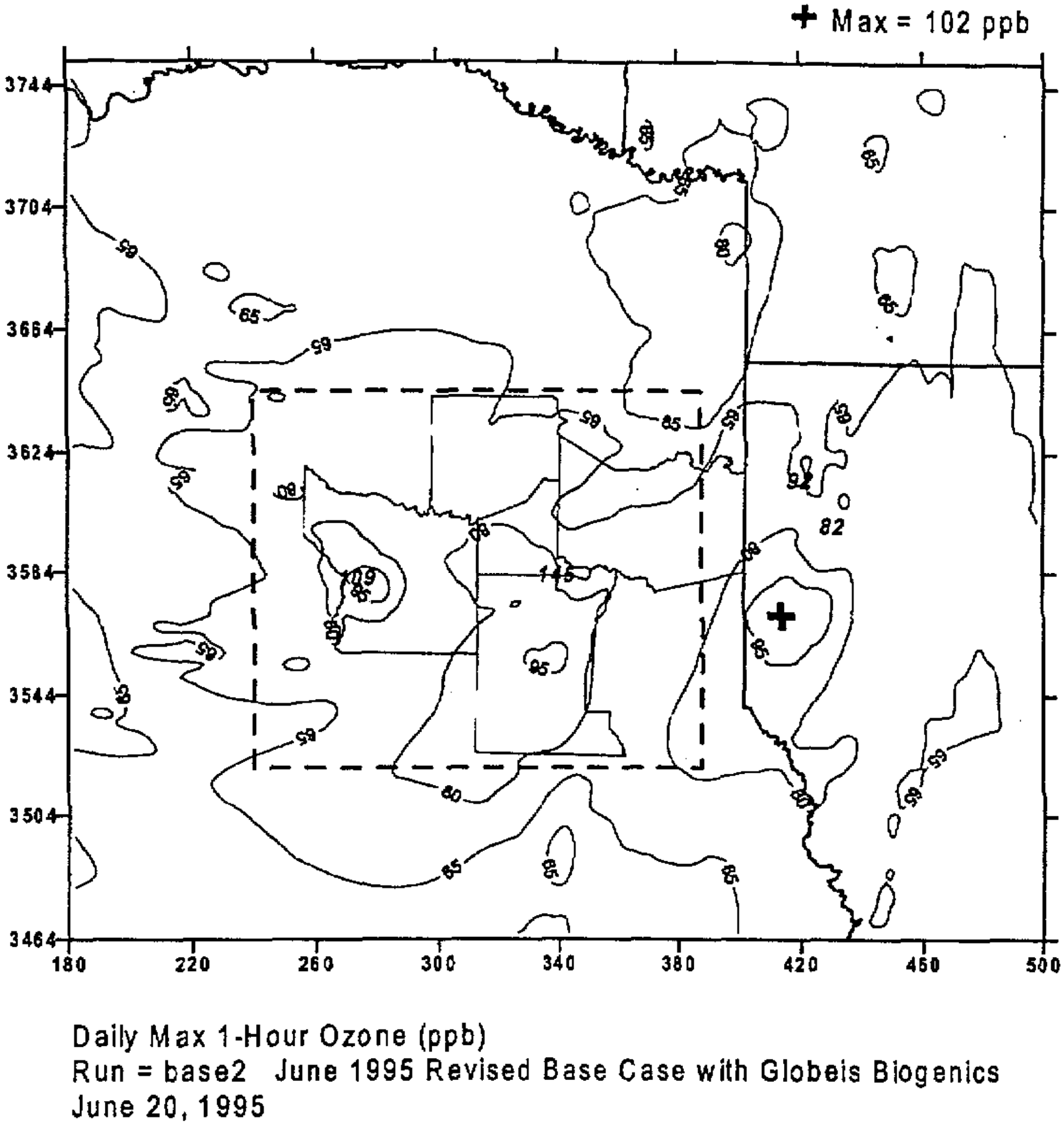


Figure 5-19. Isopleth of daily maximum 1-hour ozone predictions (with observations) for the final base case (base2) for June 20, 1995.

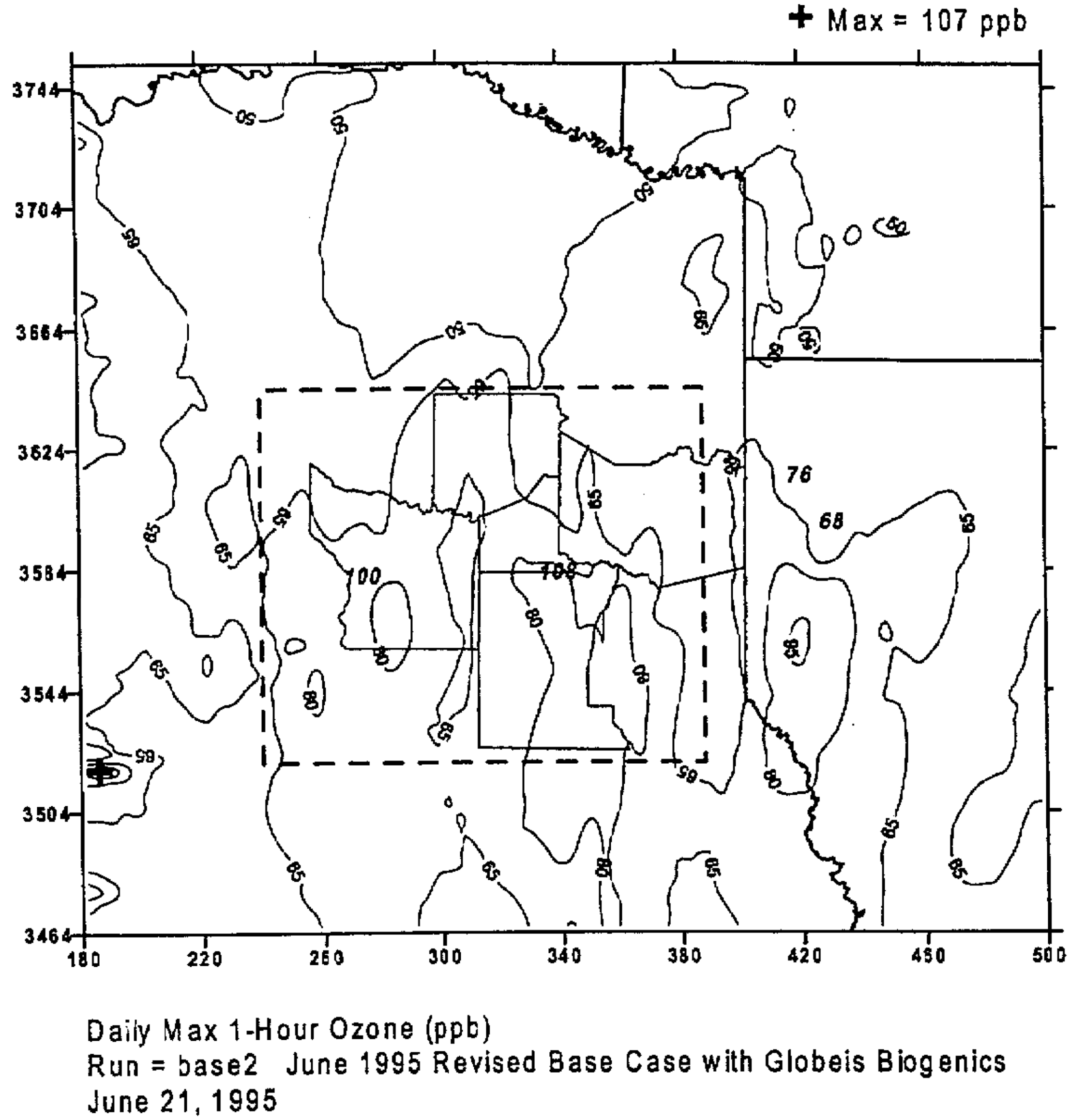
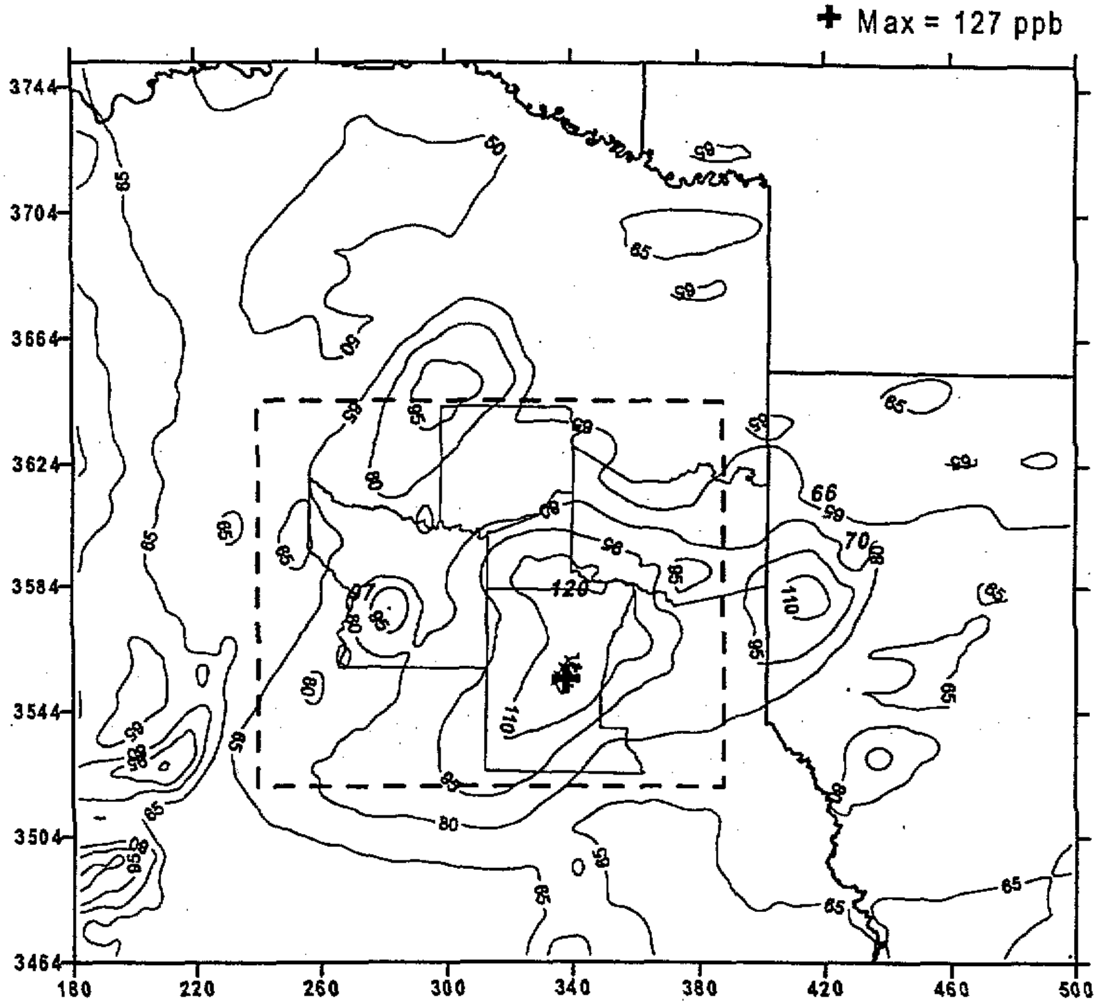


Figure 5-20. Isopleth of daily maximum 1-hour ozone predictions (with observations) for the final base case (base2) for June 21, 1995.



Daily Max 1-Hour Ozone (ppb)
Run = base2 June 1995 Revised Base Case with Globeis Biogenics
June 22, 1995

Figure 5-21. Isopleth of daily maximum 1-hour ozone predictions (with observations) for the final base case (base2) for June 22, 1995.

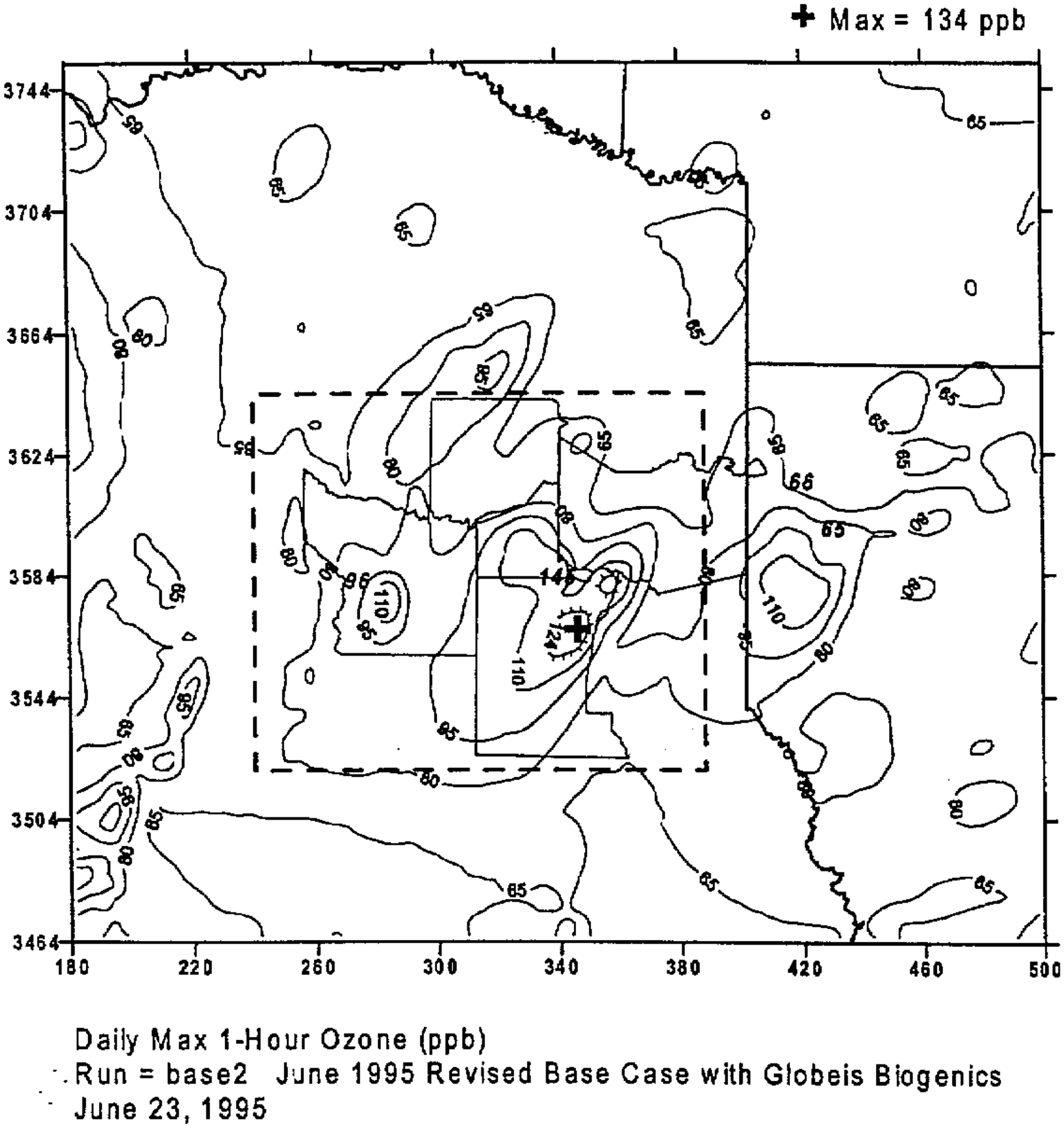


Figure 5-22. Isopleth of daily maximum 1-hour ozone predictions (with observations) for the final base case (base2) for June 23, 1995.

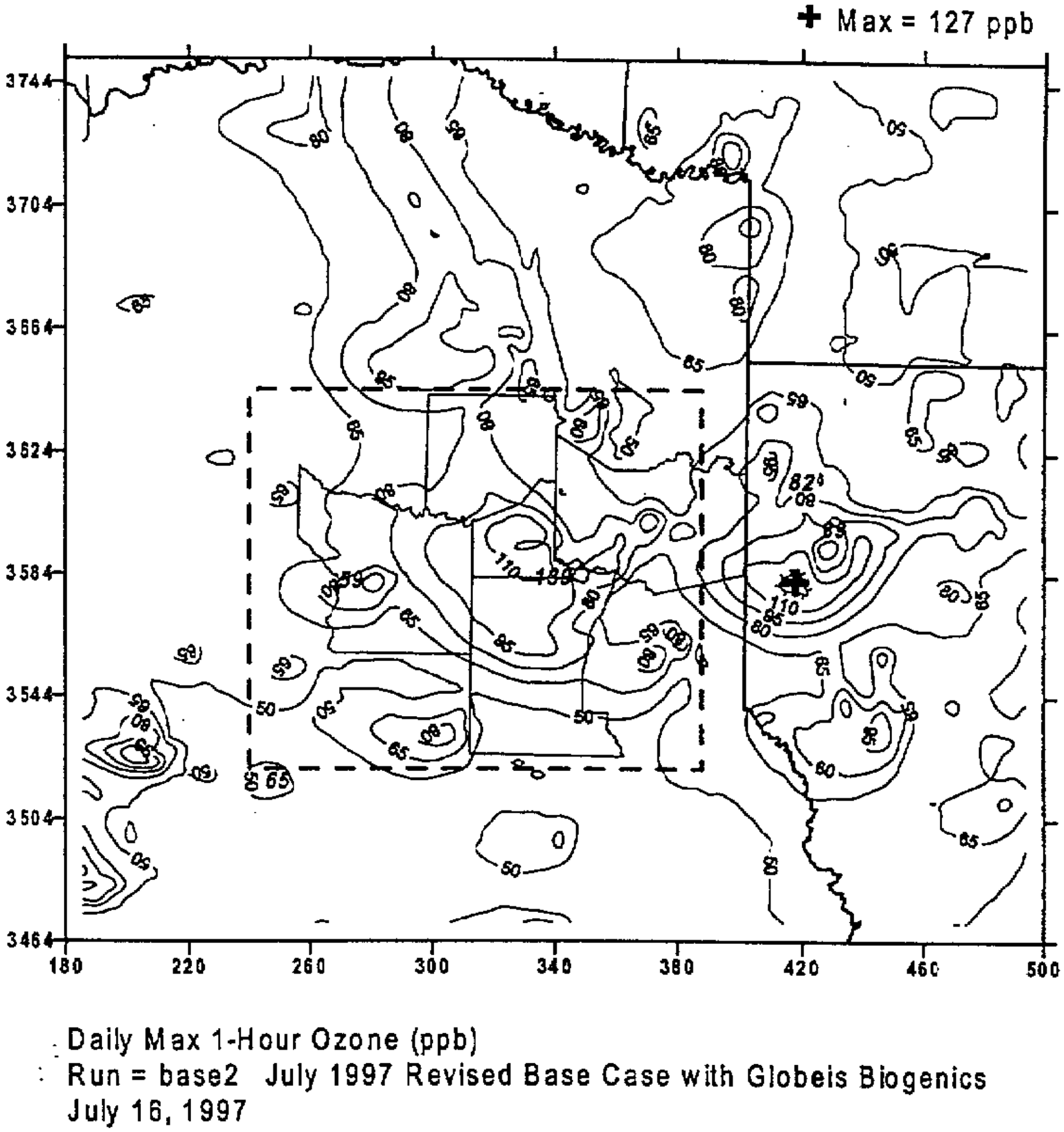


Figure 5-23. Isopleth of daily maximum 1-hour ozone predictions (with observations) for the final base case (base2) for July 16, 1997.

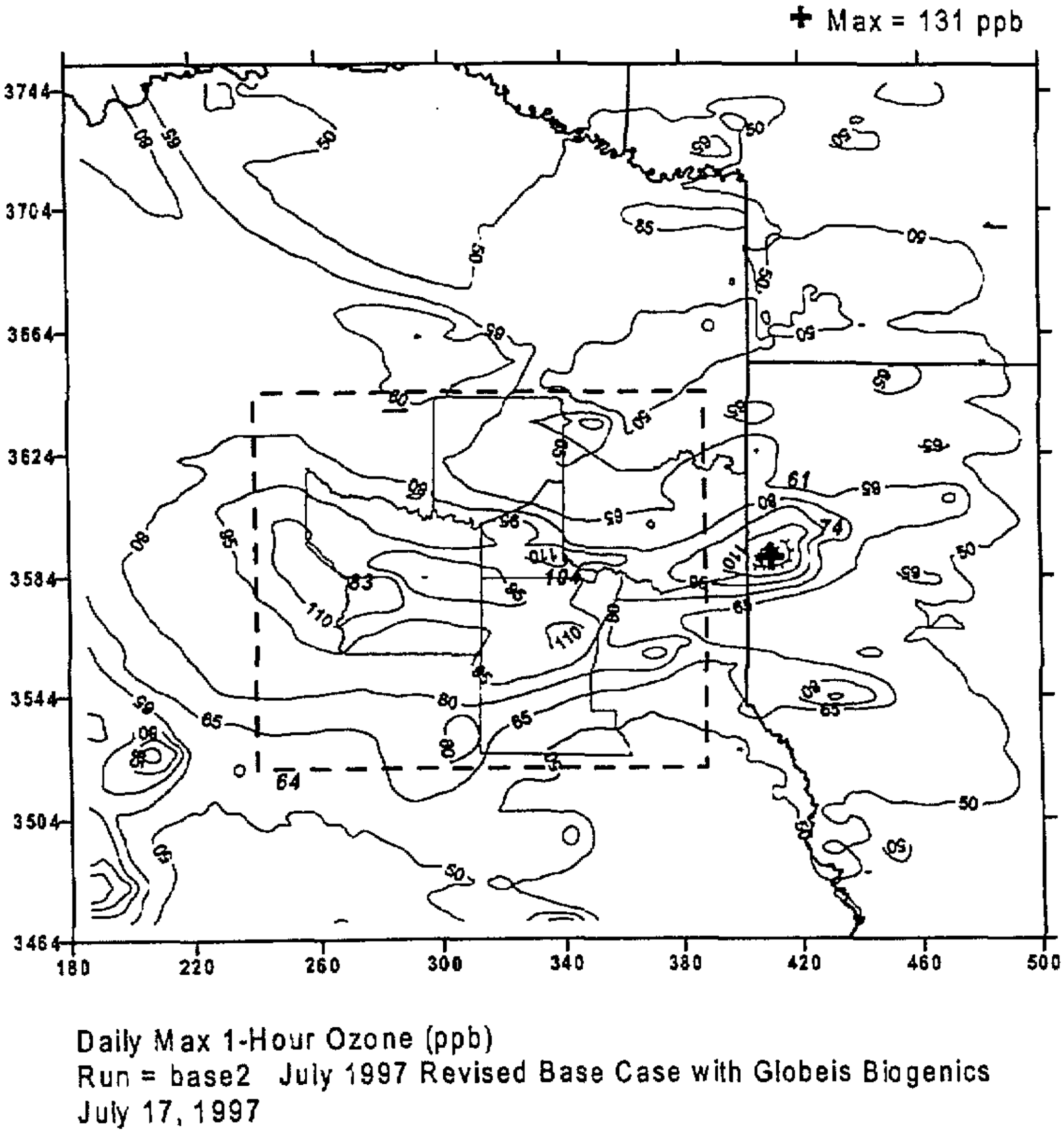


Figure 5-24. Isopleth of daily maximum 1-hour ozone predictions (with observations) for the final base case (base2) for July 17, 1997.

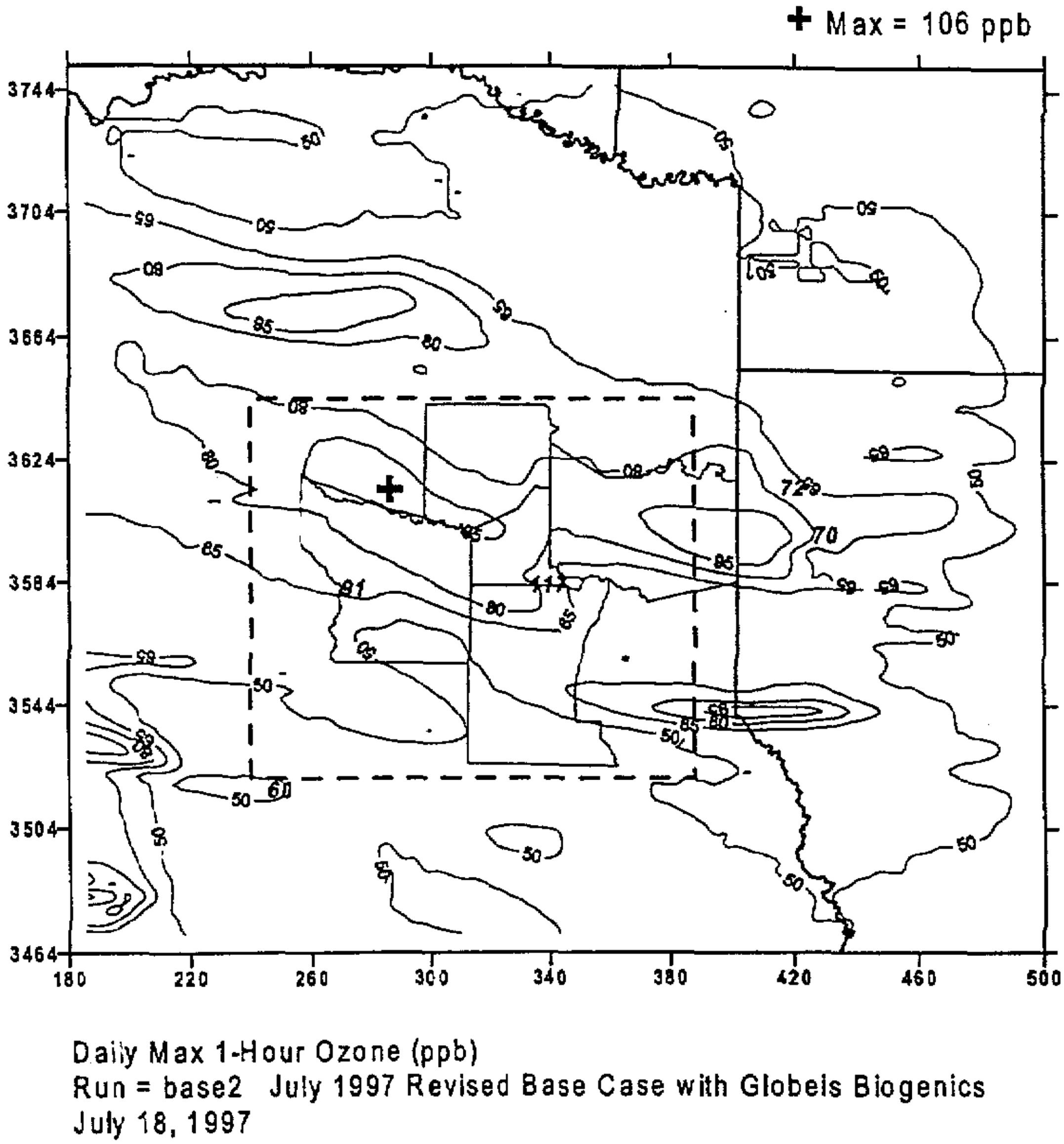


Figure 5-25. Isopleth of daily maximum 1-hour ozone predictions (with observations) for the final base case (base2) for July 18, 1997.

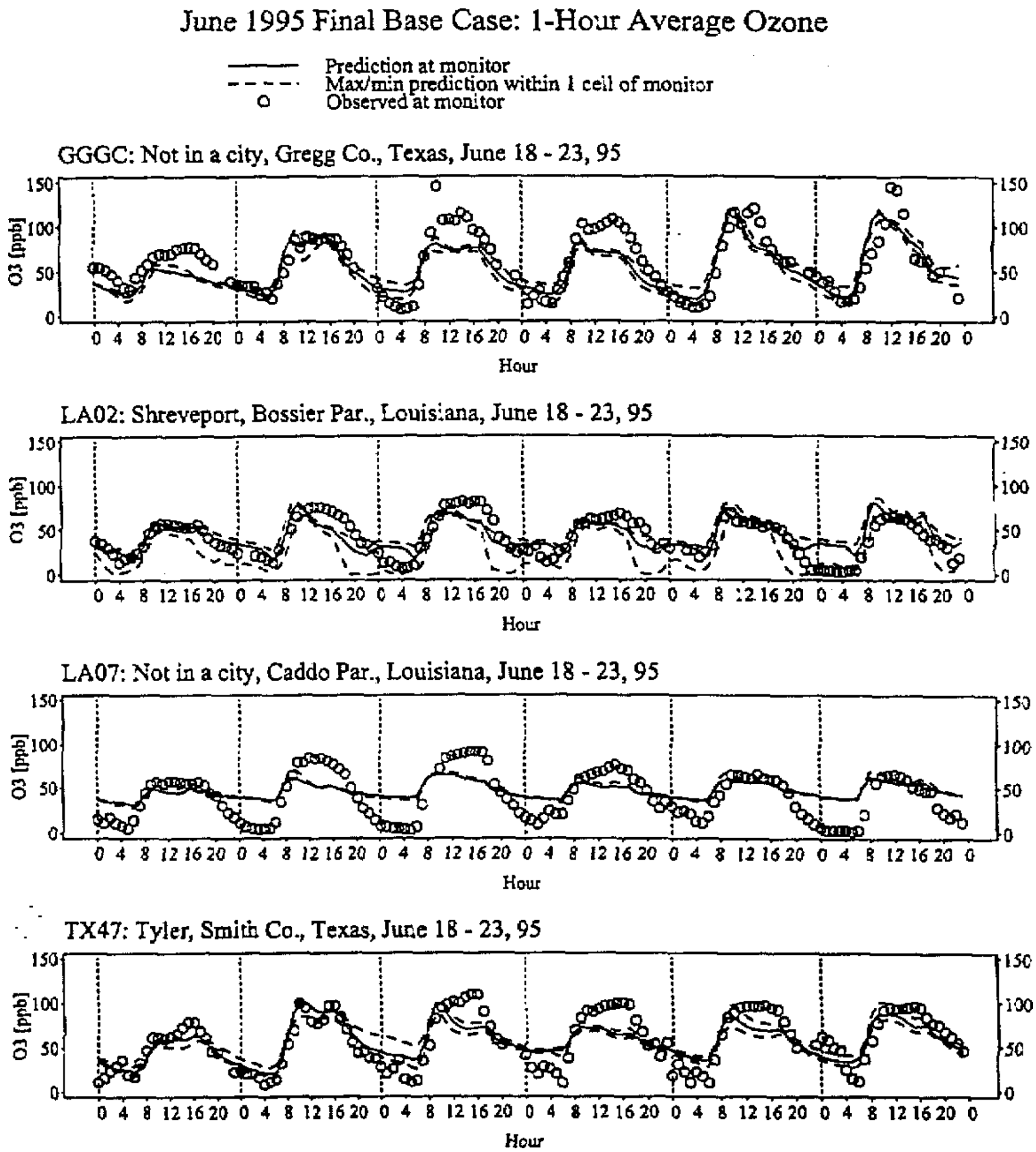


Figure 5-26. Time series of 1-hour ozone predictions and observations for the final base case (base2) for June 1995.

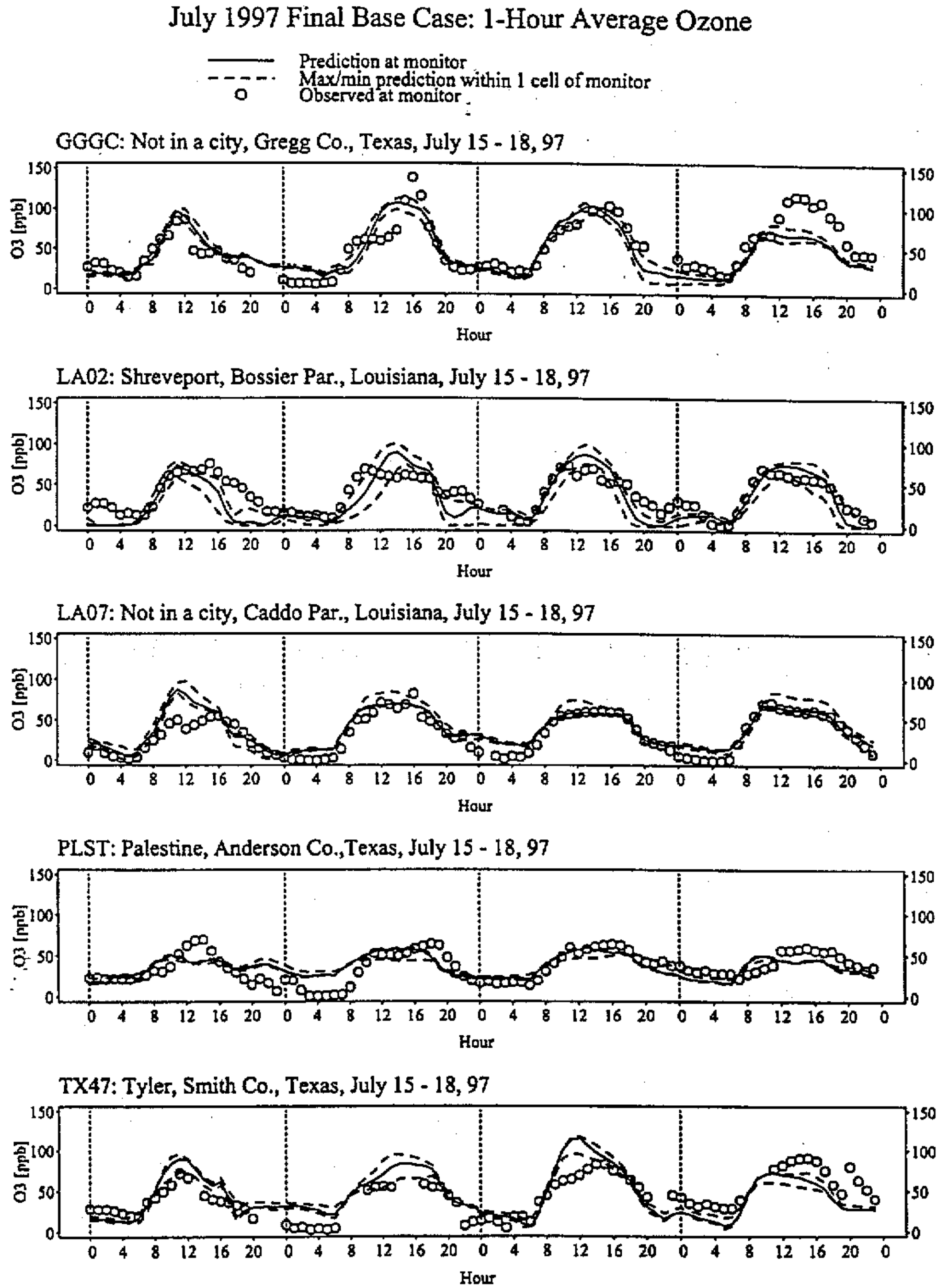


Figure 5-27. Time series of 1-hour ozone predictions and observations for the final base case (base2) for July 1997.

6. FUTURE YEAR MODELING

Future year modeling was performed for 2007 using the June 1995 regional scale model and the July 1997 urban scale model. The only difference between the base and future year modeling was changes to the anthropogenic emissions inventory to reflect thee impacts of growth and emission controls. In some modeling studies boundary conditions are reduced for the future year modeling, but that was not done here because the base year boundary conditions were already at background levels.

The 2007 base case modeling shows whether ozone levels are expected to exceed the ozone NAAQS in the future. Reductions in emissions (control strategies) were modeled to identify measures that could lead to attainment of the ozone NAAQS in the future. The approach to control strategy development is discussed further below.

8-Hour Ozone

In light of the current uncertainty surrounding the 1-hour ozone standard, control strategy development was performed relative to the 1-hour standard. However, impacts of control strategies on 8-hour ozone were evaluated using the methodologies described in the most recent draft EPA guidance. The impacts of control strategies on 8-hour ozone are described separately in Section 7.

OVERVIEW OF CONTROL STRATEGY DEVELOPMENT

The NETAC Technical Committee developed a plan to evaluate control strategies in several "rounds" of modeling. Early rounds considered general reductions in emissions from broad source categories across wide geographic areas. Later rounds focused in on the most effective general strategies to refine the level of control and geographic area over which controls are needed. The final rounds looked at specific strategies to demonstrate attainment of the ozone NAAQS. In addition, the updated information on biogenic emissions developed through base year diagnostic analyses was factored into the final rounds of modeling.

Four rounds of modeling were performed, as follows:

Round 1 – Controls on broad emission categories.
Round 2 – Different levels of control and geographic area.
Round 3 – Specific control measures and revisions to biogenic emissions.
Round 4 – Final control measures and final biogenic emission inventory.

Biogenic Emissions

Changes were made to the biogenic emission inventory after control strategy Round 2 was completed. Thus, the Round 1 and Round 2 control strategy results used the same biogenic emissions as the preliminary base year base case (Base1, see Section 5). For Rounds 3 and 4, the biogenic emissions were changed between control strategies as described below. The final control strategy uses the same biogenic emissions (Globeis2) as the final base year base case (Base2).

The presentation of the control strategy results in this section follows the four rounds.

2007 BASE CASE

The 2007 base case peak 1-hour ozone levels are summarized by episode in Tables 6-1 and 6-2. Peak ozone is reported for the locations of the Tyler and Longview monitors and also for the regionwide peak in the "East Texas Sub-Domain". This sub-domain essentially covers the 5 NETAC counties so that all high ozone levels in the NETAC area are accounted for, but high ozone levels outside this area (e.g., Shreveport) are excluded. This discussion focuses on the peak 1-hour ozone levels because they are the basis for demonstrating attainment of the 1-hour ozone standard (discussed below).

For the June 1995 episode, peak 1-hour ozone levels generally decrease slightly at Tyler but increase at Longview. The sub-domain peak increases by 2-4 ppb on all days except June 20 when it decreases. For the July 1997 episode, peak 1-hour ozone levels decrease slightly at Tyler, do not change or decrease very slightly at Longview and decrease slightly for the sub-domain peak.

Overall, the changes in peak 1-hour ozone are mostly small between the base and future years. This is consistent with the relatively small changes in NOx emissions between the base and future years (secstion4) bearing in mind the base case sensitivity results showed that peak ozone levels mainly respond to NOx emission levels. Because the emissions and ozone levels are similar between the base and future years it is likely that the emissions sensitivity results developed for the base year are highly relevant to the future year.

Table 6-1. Summary of peak 1-hour ozone concentrations (ppb) for June 1995.

	Longview				**Tyler**				**East Texas Sub-Domain**			
	6/20	**6/21**	**6/22**	**6/23**	**6/20**	**6/21**	**6/22**	**6/23**	**6/20**	**6/21**	**6/22**	**6/23**
Observed	145	108	120	145	109	100	97	96	145	108	120	145
1995	89	95	130	119	111	73	86	89	118	109	142	140
2007	91	96	133	127	108	73	85	85	114	111	145	144
2007-1995	2	1	3	8	-3	0	-1	-4	-4	2	3	4

Table 6-2. Summary of peak 1-hour ozone concentrations (ppb) for July, 1997.

	Longview			**Tyler**			**East Texas**		
	7/16	**7/17**	**7/18**	**7/16**	**7/17**	**7/18**	**7/16**	**7/17**	**7/18**
Observed	139	104	117	-999	83	91	139	104	117
1997	109	104	75	85	117	74	125	125	110
2007	109	103	75	83	116	73	121	123	108
2007-1997	0	-1	0	-2	-1	-1	-4	-2	-2

ROUND 1 CONTROL STRATEGIES

Three control strategies were selected for Round 1:

Control 1 – 30% reduction in elevated point source NOx emissions in the 4km grid area.

Control 2 – 30% reduction in on-road mobile source NOx emissions in the 4km grid area.

Control 3 – 30% reduction in area, nonroad and low level point source NOx emissions in the 4km grid area.

Control strategies for 1-hour ozone must be designed according to the 1-hour ozone attainment demonstration methodology defined by EPA. In essence, this methodology says that on all modeling days for which the base case model performance satisfies the EPA guidance, all model grid cells must have ozone of 125 ppb or lower. The modeling days with satisfactory model performance are:

June 1995 episode – June 22 and 23
July 1997 episode – July 16 and 17

For each of these days, the highest ozone level that must be controlled is the peak 1-hour ozone level in the East Texas sub-domain. Thus, the attainment test boils down to reducing this sub-domain peak below 125 ppb on the days with acceptable model performance.

Table 6-3 summarizes the effects of control strategies 1-3 on peak ozone by episode, and composited over episodes. Peak 1-hour ozone values greater than 125 ppb are in bold. A successful control strategy will have no bold values. From this point of view, only the bottom panel of Table 6-3 (the episode composite) is strictly necessary since this summarizes the highest peak 1-hour ozone levels. The top panels are provided to show the break-down by episode. Ozone isopleth plots of maximum 1-hour ozone are included in Appendix A for the 2007 base case.

In addition to peak ozone, Table 6-3 also shows relative reduction factors (RRFs). These are included to provide a way of comparing control strategy effectiveness between episodes and locations. The RRFs are not used in the 1-hour attainment test, although RRFs do form the basis of the new 8-hour attainment test. The RRF is calculated as the ratio of average peak ozone for the control strategy divided by the average peak ozone for the 2007 base case (where the averages are over episode days).

The RRFs in Table 6-3 show that for Longview and the sub-domain peak, controls on elevated point source NOx (Control 1) are much more effective in reducing 1-hour ozone that controls on other sources (Control 2 and 3). For Tyler, controlling on-road mobile NOx (Control 2) and other low level NOx (Control 3) is relatively more effective, nearly comparable to controlling elevated point source NOx; however, note that no reductions in 1-hour ozone are needed in the Tyler area because 2007 base case ozone is less that 125 ppb.

Table 6-3. Summary of peak 1-hour ozone levels (ppb) and relative reduction factors (RRFs).

	Longview		Tyler		East Texas Sub-domain	
	Peak	RRF	Peak	RRF	Peak	RRF
June 22-23, 1995						
2007 Base Case	**133**		85		**145**	
Control 1	119	0.90	80	0.94	**132**	0.90
Control 2	**131**	0.98	81	0.95	**144**	0.99
Control 3	**129**	0.97	81	0.95	**143**	0.99
July 16-17, 1997						
2007 Base Case	109		116		123	
Control 1	102	0.93	106	0.94	122	0.98
Control 2	109	0.99	114	0.97	120	0.98
Control 3	108	0.98	113	0.96	120	0.98
Episode Composite						
2007 Base Case	**133**		116		**145**	
Control 1	119	0.92	106	0.94	**132**	0.93
Control 2	**131**	0.99	114	0.96	**144**	0.99
Control 3	**129**	0.97	113	0.96	**143**	0.98

ROUND 2 CONTROL STRATEGIES

The emission control strategies to be evaluated in Round 2 were selected by the NETAC Technical Committee on August 13, 1999. All of the Round 1 and 2 control strategies are summarized in Table 6-4.

Table 6-4. Round 1 and 2 Control Strategies.

Strategy Number	Percent reduction in NOx emissions from: Major Point	On-Road Mobile	Other Anthropogenic	Geographic Area
Round 1				
Cntl1	30	0	0	4 km grid extent
Cntl2	0	30	0	4 km grid extent
Cntl3	0	0	30	4 km grid extent
Round 2				
Cntl4	50	0	0	4 km grid extent
Cntl5	70	0	0	4 km grid extent
Cntl6	50	30	0	4 km grid extent
Cntl7	50	0	30	4 km grid extent
Cntl8	50	30	30	4 km grid extent
Cntl9	50	30	30	5 county area
Cntl10	50	30	30	17 county area

Notes to Table 6-4:
1. Other anthropogenic means all anthropogenic sources except major points and on-road mobile, i.e., area plus nonroad mobile plus low level point sources.
2. The geographic area is the area over which the controls are to be applied.
3. The extent of the 4 km grid is shown in Figure 6-2.
4. The 5 county area is Gregg, Harrison, Rusk, Smith and Upshur.
5. The 17 county area is Camp, Cherokee, Franklin, Gregg, Harrison, Henderson, Marion, Morris, Nacogdoches, Panola, Rusk, Shelby, Smith, Titus, Upshur, Van Zandt and Wood.

The design for Round 2 was developed by the NETAC Technical Committee in consultation with the TNRCC and EPA. The rationale can be summarized briefly, as follows:

- The main goal of Round 2 is to further refine the types of controls that are effective in reducing ozone and to narrow down the level of controls needed. Round 2 does not focus on highly specific measures such as individual facility reductions or cleaner burning gasoline.

- Strategies 4 and 5 refine the level of "across the board" point source NOx control required to demonstrate attainment of the 1-hour ozone standard.

- Strategies 6-8 investigate the effectiveness of controls on mobile and other sources of NOx in combination with 50% reductions from major point sources.

- Strategies 8-10 investigate the effect on ozone of the geographic area over which controls are applied for "50/30/30" across the board reductions in point, mobile and other sources of NOx.

Ozone Reductions

Control strategies for 1-hour ozone must be designed according to the 1-hour ozone attainment demonstration methodology defined by EPA. In essence, this methodology says that on all modeling days for which the base case model performance satisfies the EPA guidance, all model grid cells must have ozone of 124 ppb or lower. The modeling days with satisfactory model performance are June 22 and 23, 1995 and July 16 and 17, 1997.

For each of these days, the highest ozone level that must be controlled is the peak 1-hour ozone level in the East Texas sub-domain. Thus, the attainment test boils down to reducing this sub-domain peak below 125 ppb on the four days with acceptable model performance.

Table 6-5 summarizes the effects of control strategies 1-10 on peak ozone by episode, and composited over episodes. Peak 1-hour ozone values of 125 ppb or greater are shown in bold. A successful control strategy will have no bold values. From this point of view, only the episode composite peak ozone (bottom right of Table 6-5) is strictly necessary since this gives the single highest 1-hour ozone level for each strategy. The rest of the table shows the break-down by episode and monitor location. Note that no reductions in 1-hour ozone are needed in the Tyler area because 2007 base case ozone is less that 125 ppb. Reductions in 1-hour ozone are needed at Longview and at the location of the peak 1-hour ozone concentration in the East Texas sub-domain.

In addition to peak ozone values, Table 6-5 also shows relative reduction factors (RRFs). These are included to provide a way of comparing control strategy effectiveness between episodes and locations. The RRFs are not used in the 1-hour attainment test. The RRF is calculated as the ratio of average peak ozone for the control strategy divided by the average peak ozone for the 2007 base case (where the averages are over episode days).

Of the strategies modeled so far only Cntl6 meets the 1-hour attainment test. As reported in Table 6-5, and shown graphically in Figure 6-1, Cntl6 has an episode composite peak 1-hour ozone of 124 ppb whereas all other strategies are 126 ppb or higher. This result is initially surprising since some other strategies (e.g., Cntl5 and Cntl8) have greater emission reductions than Cntl6. Figure 6-1 (and Table 6-5) shows that there is a key difference between the June 1995 and July 1997 episodes: for the June 1995 episode peak ozone levels decrease in response to greater NOx emission reductions from Cntl4 to Cntl5 and Cntl8; for the July 1997 episode peak ozone levels increase from Cntl4 to Cntl5 and Cntl8. This response for the July 1997 episode seems counter-intuitive, but is an example of an effect called a "NOx disbenefit." The NOx disbenefit for the July 1997 episode is discussed further below.

The difference in the response of the two episodes to NOx emission controls will complicate the design of control strategies in Round 3. The strategies evaluated in Rounds 1 and 2 show that at least one "across the board" strategy is effective (Cntl6), and it is likely that there are many other strategies that will also work. In designing the Round 3 strategies it will become important to carefully consider the location of major point sources in combination with prospective emissions reductions. Therefore, a map of point source locations is provided in Figure 6-2(a). The sources included in Figure 6-2(a) are the ones for which 2007 emission levels were previously described for the Round 1 results. In addition, Figure 6-2(b) shows the location and emissions (tons/day) for all elevated point sources in the 4km domain with emissions greater than 2 tons/day. The emissions shown in Figure 6-2(b) are day specific for the 2007 base case, July 15 1997 scenario, and emissions from multiple stacks at the same facility have been aggregated to get the total tons/day for each facility.

The discussion of the Round 2 results below is broken into three sections that analyze the results according to the way the strategies were designed.

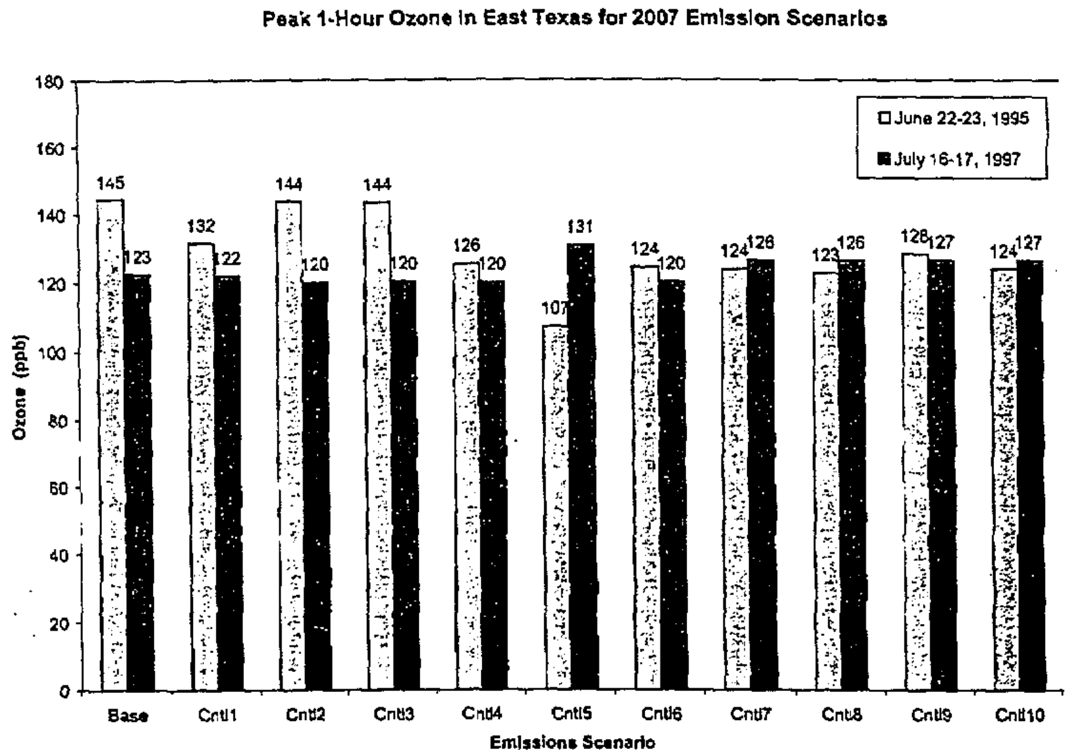


Figure 6-1. Peak 1-hour ozone in East Texas for all Round 1 and 2 control strategies, by episode.

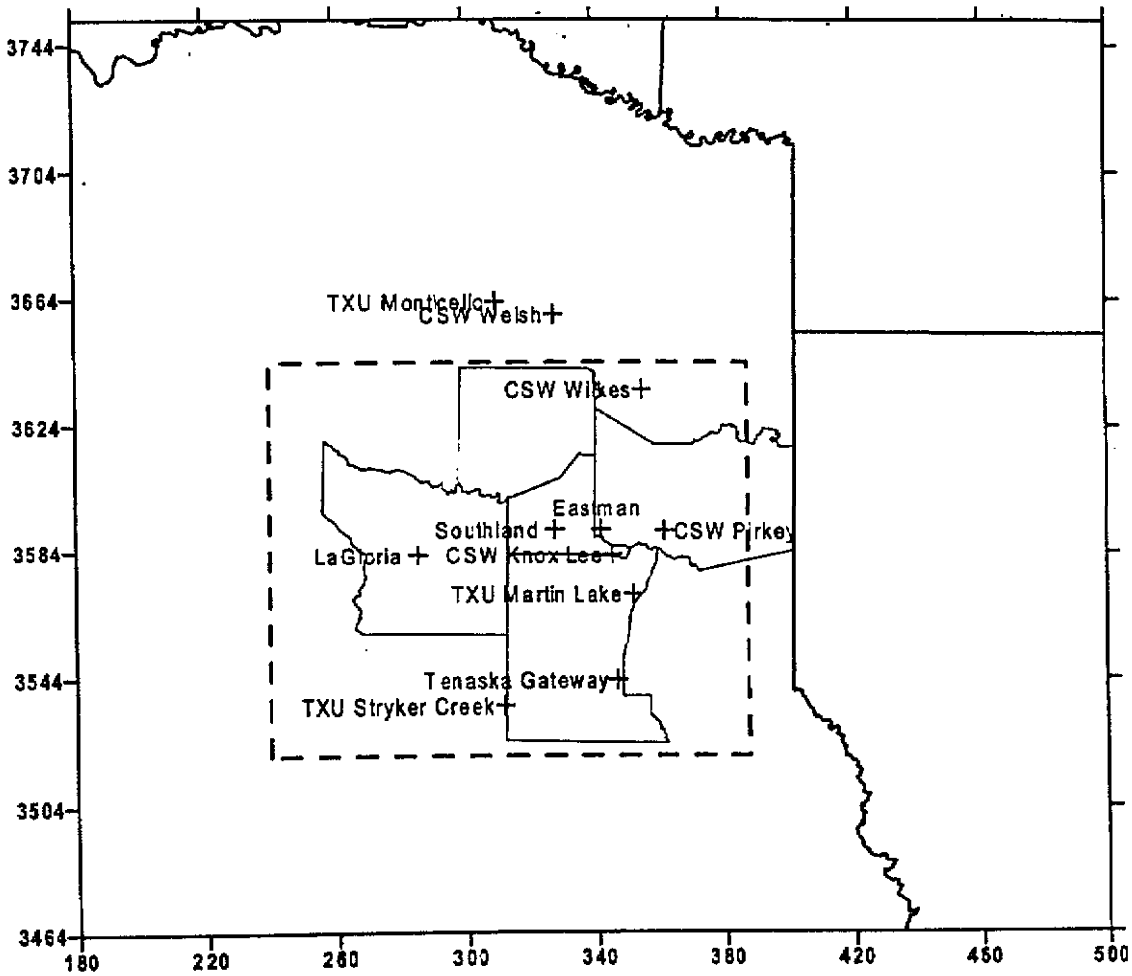


Figure 6-2(a). Name and location of point sources in East Texas.

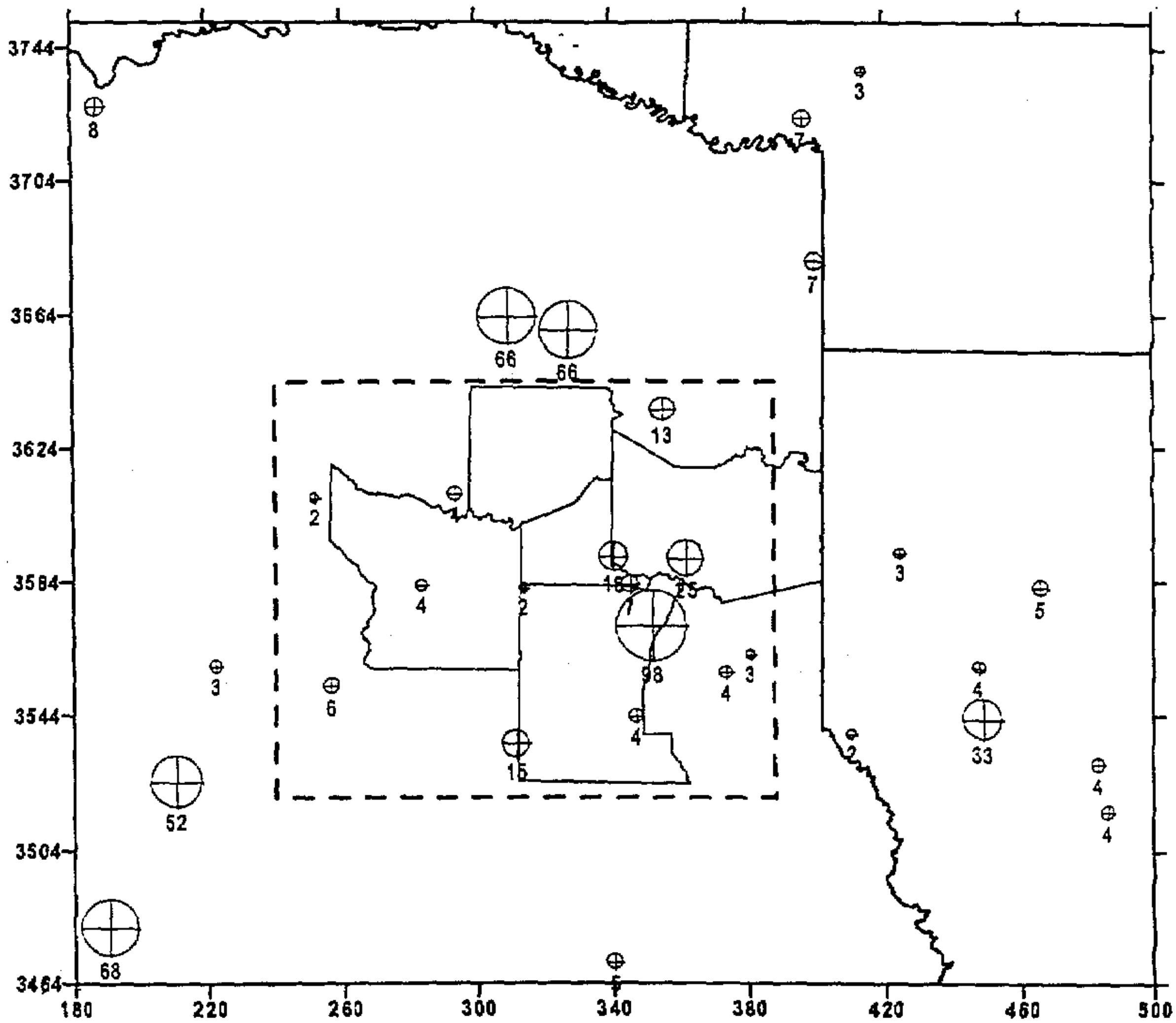


Figure 6-2(b). Emissions of NOx (tons/day) for all elevated point sources greater than 2 tons/day in the 4km domain. Emissions are day specific for the 2007 base case, July 15 1997 scenario. Emissions from multiple stacks at the same facility have been aggregated.

Table 6-5. Peak 1-hour ozone levels (ppb) and relative reduction factors (RRFs).

	Longview		Tyler		East Texas Sub-domain	
	Peak	RRF	Peak	RRF	Peak	RRF
June 22-23, 1995						
2007 Base Case	133		85		145	
Cntl1	119	0.90	80	0.94	132	0.90
Cntl2	131	0.98	81	0.95	144	0.99
Cntl3	129	0.97	81	0.95	144	0.99
Cntl4	110	0.84	77	0.90	126	0.83
Cntl5	*100*	*0.76*	*73*	*0.86*	*107*	*0.74*
Cntl6	108	0.83	72	0.84	124	0.82
Cntl7	107	0.81	72	0.85	124	0.81
Cntl8	105	0.79	67	0.79	123	0.81
Cntl9	108	0.82	73	0.86	128	0.84
Cntl10	106	0.81	69	0.80	124	0.82
July 16-17, 1997						
2007 Base Case	109		116		123	
Cntl1	*102*	*0.92*	*106*	*0.94*	*122*	*0.98*
Cntl2	109	0.99	114	0.97	120	0.98
Cntl3	108	0.98	113	0.96	120	0.98
Cntl4	95	0.86	97	0.89	120	0.94
Cntl5	85	0.78	88	0.83	131	0.97
Cntl6	94	0.84	94	0.85	120	0.94
Cntl7	92	0.83	93	0.84	126	0.96
Cntl8	91	0.81	90	0.81	126	0.95
Cntl9	92	0.85	94	0.83	127	0.98
Cntl10	92	0.85	93	0.82	127	0.97
Episode Composite						
2007 Base Case	133		116		145	
Cntl1	119	0.91	106	0.94	132	0.93
Cntl2	131	0.99	114	0.96	144	0.99
Cntl3	129	0.97	113	0.96	144	0.99
Cntl4	*110*	*0.85*	*97*	*0.89*	*126*	*0.88*
Cntl5	100	0.77	88	0.84	131	0.85
Cntl6	108	0.83	94	0.85	124	0.88
Cntl7	107	0.82	93	0.85	126	0.88
Cntl8	105	0.80	90	0.80	126	0.87
Cntl9	108	0.83	94	0.84	128	0.90
Cntl10	106	0.83	93	0.81	127	0.89

Impact of Major Point Source NOx Reductions

The impact of NOx emissions from major point sources on peak ozone levels can be seen by comparing 4 scenarios: 2007 base case, cntl1 (30% reduction), cntl4 (50% reduction) and cntl5 (70% reduction) strategies. This comparison can be made from Table 6-5 and is shown graphically in Figure 6-3. The June 1995 episode shows a progressive decrease in peak 1-

hour ozone from 145 ppb in the base case to 107 ppb in Cntl5 (70% reduction). Table 6-4 shows similar response at the Longview and Tyler monitoring locations with larger emission reductions leading to progressively lower ozone.

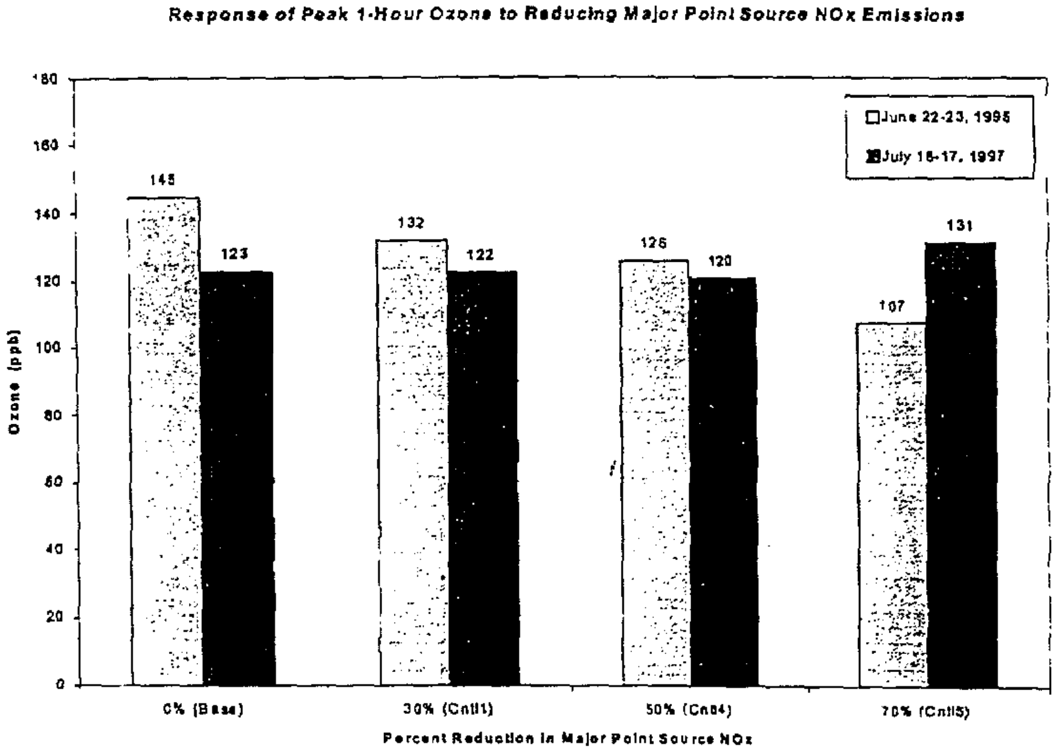


Figure 6-3. Impact of across the board reductions in major point source NOx emissions on 1-hour ozone.

For the July 1997 episode, peak 1-hour ozone levels decrease progressively from 123 ppb in the base case to 120 ppb in Cntl4 with a 50% emission reduction. However, when emissions are further lowered to 70% reduction peak ozone levels increase to 131 ppb. This effect is an example of a NOx disbenefit – a situation where reducing NOx emissions leads to an increase in ozone. This response can be explained by looking at an isopleth plot of the difference in daily maximum ozone between Cntl4 and the 2007 base case (Figure 6-4) for July 16, 1997. In Figure 6-4, ozone reductions appear as negative numbers and dashed lines. Figure 6-4 shows that in most areas daily maximum ozone decreases in response to a 50% reduction in major point source NOx emissions. A notable exception is the single grid cell containing the Texas Eastman facility (at the location of the plus sign) where maximum ozone increase by 35 ppb. This is where the NOx disbenefit effect occurs. It happens because NOx levels in this grid cell are sufficiently high that they suppress ozone levels. As NOx levels are reduced by control strategies, ozone increases because the suppression effect weakens. In the 2007 base case, the maximum ozone level in this grid cell on July 16 was 85 ppb. With a 30% emissions reduction (Cntl1) ozone increased to 97 ppb, with a 50% reduction (Cntl4) ozone increased to 120 ppb, and with a 70% reduction (Cntl5) ozone increased to 131 ppb. At about the 50% emissions reduction level this grid cell becomes the peak ozone cell in the East Texas sub-domain and so starts to govern the response of the peak 1-hour ozone to emission controls. This explains how the episode peak can decrease from the base case to Cntl1 to Cntl4, but then increase in Cntl5.

There are two points to note about this phenomenon: (1) The NOx disbenefit over Texas Eastman is only apparent for July 16, 1997. There in no similar effect for the other modeling days (June 22 and 23, 1995 and July 17, 1997). (2) The NOx disbenefit increases the episode peak ozone for July 1997 above 125 ppb when across the board point source NOx reductions are more than about 50%. Emission reductions beyond 70% would bring the peak ozone level back down below 125 ppb. With the current information it is unknown how high the emissions reductions would need to be (80 percent?; 90 percent?) to bring the peak ozone back down below 125 ppb on July 16.

Strategies 6 through 10 all include a 50% reduction in emissions from major point sources. Since the NOx disbenefit effect is just on the edge of becoming important (i.e., dominating the episode peak ozone response) at this level of NOx reduction, strategies 6 through 10 may also show NOx disbenefits for the July 1997 episode. This turns out to be the case for strategies 7 through 10, as discussed further below.

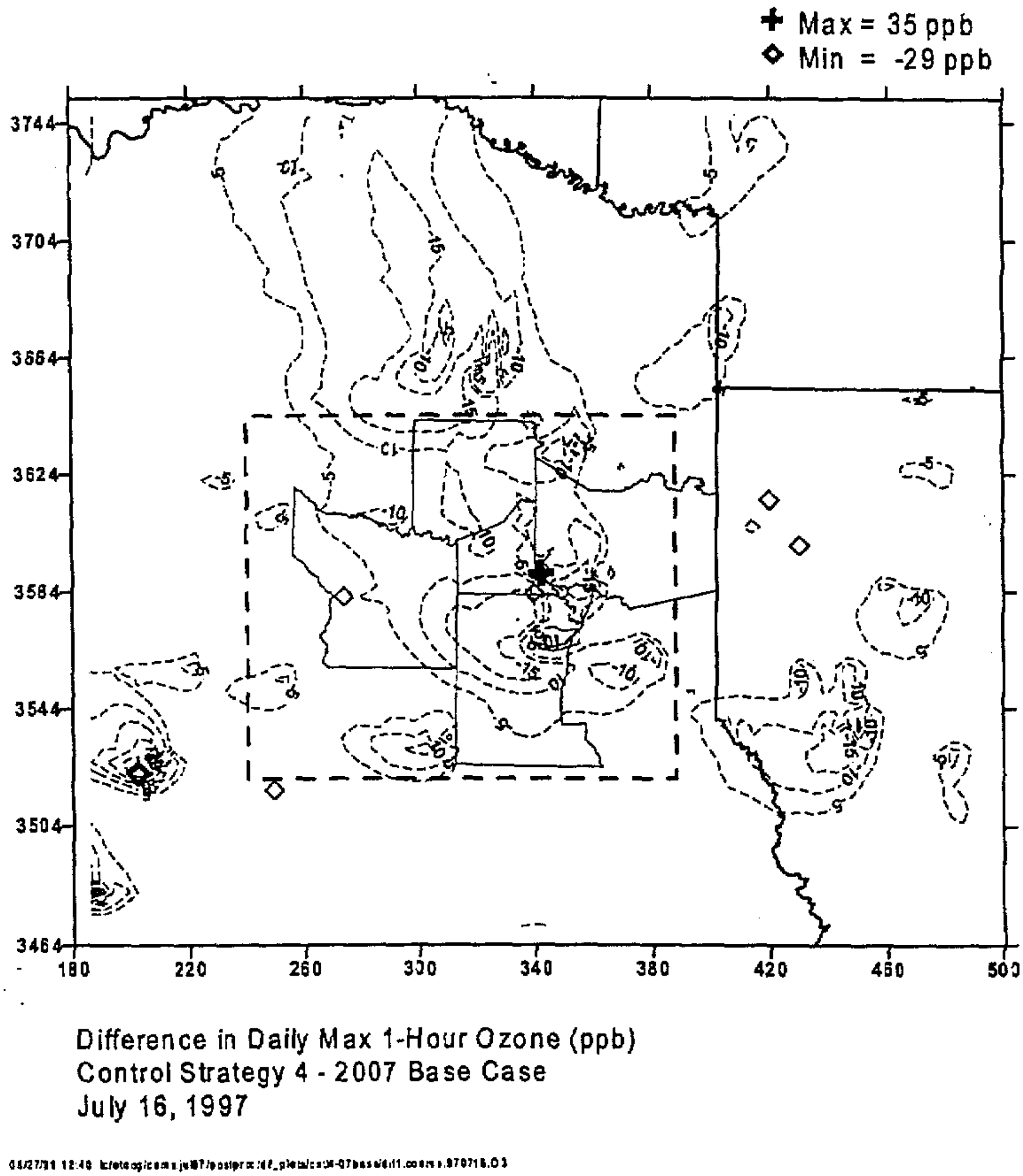


Figure 6-4. Difference in daily maximum ozone (ppb) between the Cntl4 and the 2007 base case scenarios for July 16, 1997. Ozone reductions due to the control strategy are shown as negative numbers by dashed lines.

Impact of Controls on Mobile and Other Sources of NOx in Combination with 50% Reductions from Major Point Sources

In Round 1, strategies 2 and 3 looked at the impact of reductions in NOx emissions from mobile sources and "other" sources relative to the base case. Here, "other" means area plus nonroad plus low level point sources. The conclusions from Round 1 were that for Longview and the domainwide peak, controls on NOx from mobile and other sources were much less effective than controls on elevated point source NOx. For Tyler, controlling mobile NOx and other low level NOx is relatively more effective than at Longview, and is nearly comparable in effectiveness to controlling elevated point source NOx.

For Round 2, control strategies 6 and 7 looked at the same emission reductions as strategies 2 and 3, but started from a 50% reduction in major point source NOx (Cntl4). Thus, the difference in ozone Cntl6-Cntl4 should be compared to Cntl2-base, and Cntl7-Cntl4 should be compared to Cntl3-base. These comparisons are shown for peak 1-hour ozone, by episode, in Table 6-6.

For the June 1995, episode the benefits of reducing mobile and other NOx emissions are slightly greater when the starting point is Cntl4 rather than the base case. In other words, as overall NOx levels are reduced (by the point source reductions), controls on other NOx sources become slightly more effective.

A similar pattern is seen for the July 1997 episode at Longview and Tyler - the benefits of reducing mobile and other NOx emissions are slightly greater when the starting point is Cntl4 rather than the base case. However, the response of the East Texas sub-domain peak ozone is different because of the NOx disbenefit effect described above. Starting from Cntl4 with 50% reductions for major point sources, additional controls on NOx from either mobile or other sources increase the sub-domain peak. The increase is 0.1 ppb when mobile source NOx is reduced by 30%, and 6.3 ppb when other NOx is reduced by 30%. The increase due to reducing other NOx is greater than for mobile sources because the inventory for other sources has more NOx emissions in close proximity to Texas Eastman.

Table 6-6. Reductions in peak 1-hour ozone (ppb) due to NOx reductions for mobile and other sources.

	Longview	Tyler	East Texas Sub-domain
June 22-23, 1995			
Cntl2-base	-1.8	-3.8	-0.7
Cntl3-base	-3.3	-3.6	-1.1
Cntl6-Cntl4	-1.9	-4.6	-1.1
Cntl7-Cntl4	-3.4	-4.3	-1.6
Cntl8-Cntl4	-5.6	-9.7	-2.7
July 16-17, 1997			
Cntl2-base	-0.5	-2.2	-2.6
Cntl3-base	-1.3	-2.9	-2.3
Cntl6-Cntl4	-0.9	-3.1	0.1
Cntl7-Cntl4	-2.3	-4.0	6.3
Cntl8-Cntl4	-3.3	-7.1	6.3

Strategy 8 in Round 2 looked at a combined reduction in mobile and other NOx. Comparing the impacts of Cntl8-Cntl4 to the sum of Cntl7-Cntl4 and Cntl6-Cntl4 shows that the impacts 30% reductions in mobile and other NOx are essentially additive.

Impact of Geographic Area of Controls

Strategies Cntl8 through Cntl10 investigate the impact of the geographic area over which controls are applied. The control level for this analysis was "50/30/30" percent reductions from point, mobile and other sources, respectively. The impacts on episode peak 1-hour ozone are summarized in Figure 6-5. Unfortunately, the impacts on the episode peak for the July 1997 episode are not particularly informative because the episode peak in strategies Cntl8, Cntl9 and Cntl10 is located over Texas Eastman and is strongly influenced by the NOx disbenefit effect discussed above. This effect is highly localized and may mask any impact of changing the geographic area of controls. Therefore, this discussion focuses on the results for the June 1995 episode.

For the June 1995 episode, Figure 6-5 shows that Cntl8 (4km grid extent) reduces the episode peak ozone from 145 ppb to 123 ppb. Much of this benefit can be gained by controlling emissions in just the 5 county area (Cntl9 peak is 128 ppb) and nearly all can be gained by controlling emissions in the 17 county area (Cntl10 peak is 124 ppb). This comparison is shown in a different way in Figures 6-6 (a) through (d). Figure 6-6(a) shows the 2007 base case daily maximum 1-hour ozone for June 22, the day with the highest peak ozone of 145 ppb. Figures 6-6(b) through (d) show the ozone reductions on June 22 due to Cntl8 (4km grid extent), Cntl10 (17 counties) and Cntl9 (5 counties). Shrinking the area over which controls are applied produces a corresponding shrinkage in the area over which benefits occur. However, focussing on the area where base case ozone exceeded 124 ppb inside the 5 counties (south of Longview in Figure 6-6(a) shows that most of the ozone reductions in this area come from emission reductions in the 5 county area. Ozone in this area will be most responsive to

NOx sources in the immediate vicinity (see Figure 6-2), namely the CSW Knox Lee, CSW Pirkey, Texas Eastman and TXU Martin Lake facilities.

Figure 6-6(a) shows another area where area where base case ozone exceeded 124 ppb just to the north of the five counties. Comparing Figure 6-6(a) to Figure 6-2 indicates that this area of high ozone is mainly impacted by emissions from sources in Titus county, namely the CSW Welsh and TXU Monticello facilities. The results from Cntl1 show that a 30% reduction in emissions from these two facilities is more than sufficient to bring this area below the level of the 1-hour ozone standard.

A third area where base case ozone exceeded 124 ppb is around Shreveport. From a comparison between Figures 6-6(b) and 6-6(c) it is clear that Shreveport emissions have some impact on ozone levels in East Texas, but it does not appear that Shreveport emissions play a significant role in exceeding the 1-hour ozone standard for the episodes modeled so far.

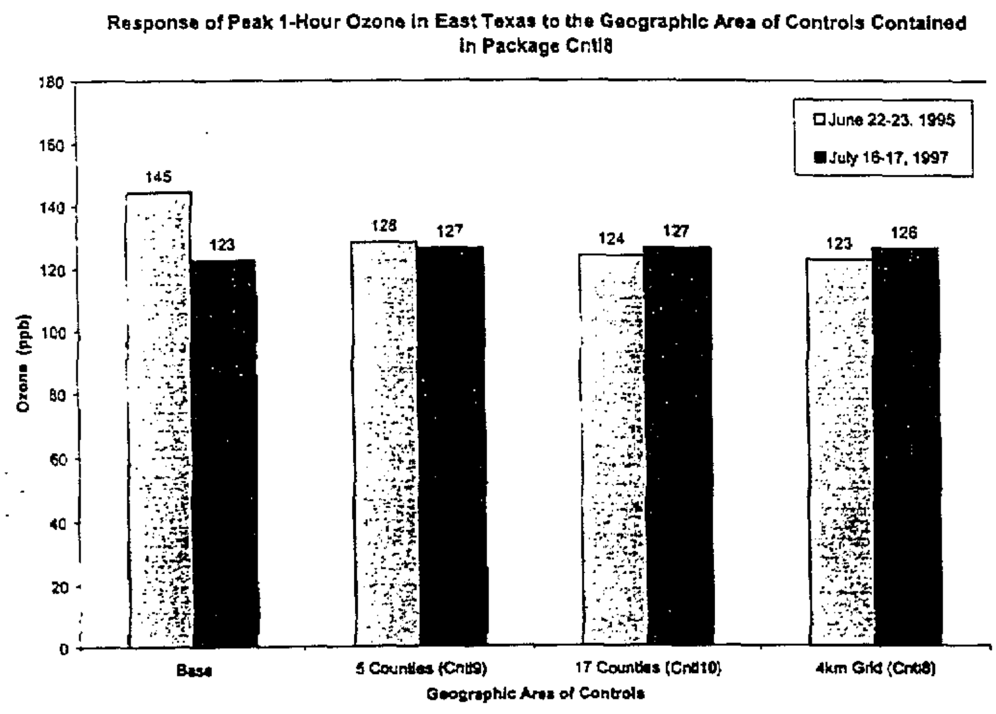
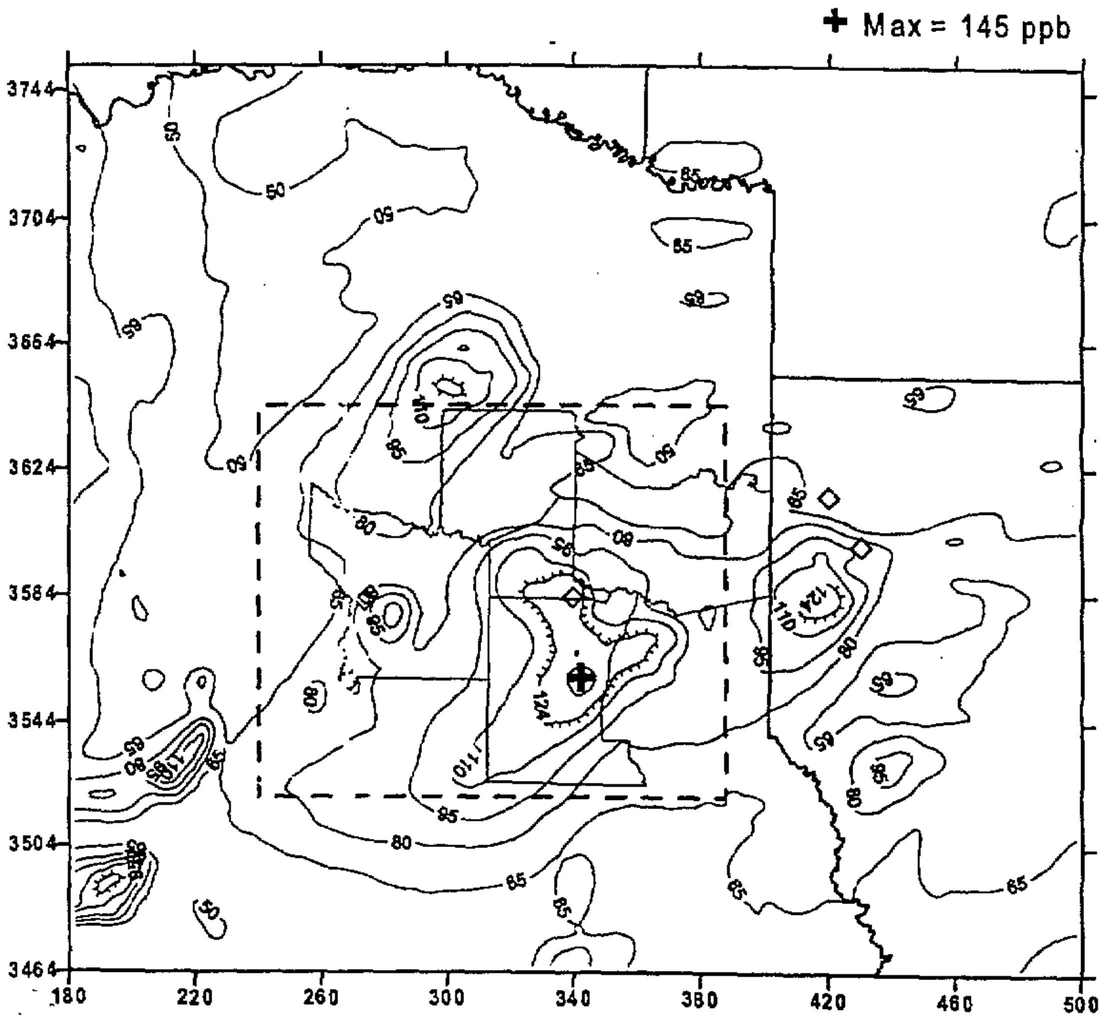
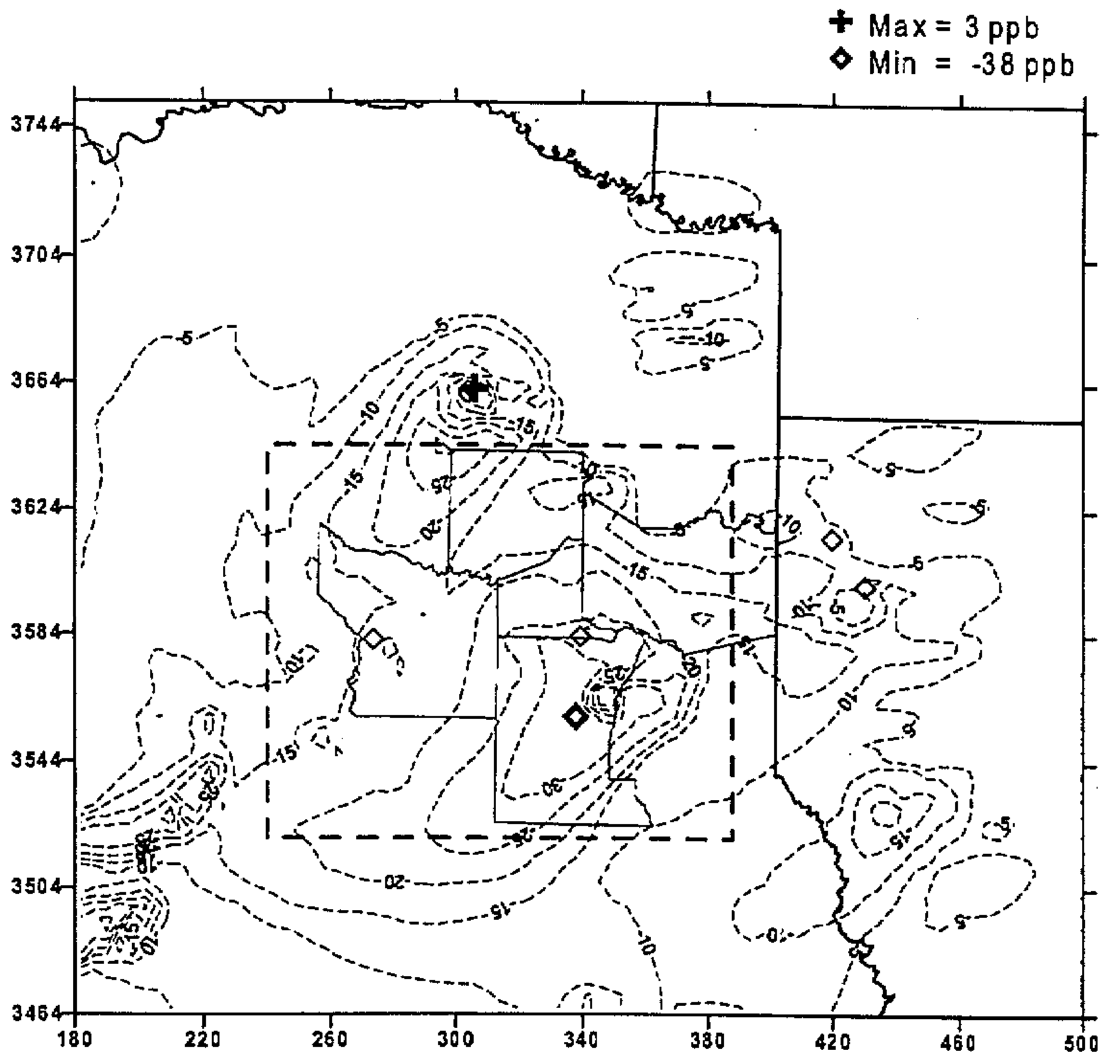


Figure 6-5. Effect of geographic area of controls on peak 1-hour ozone levels.



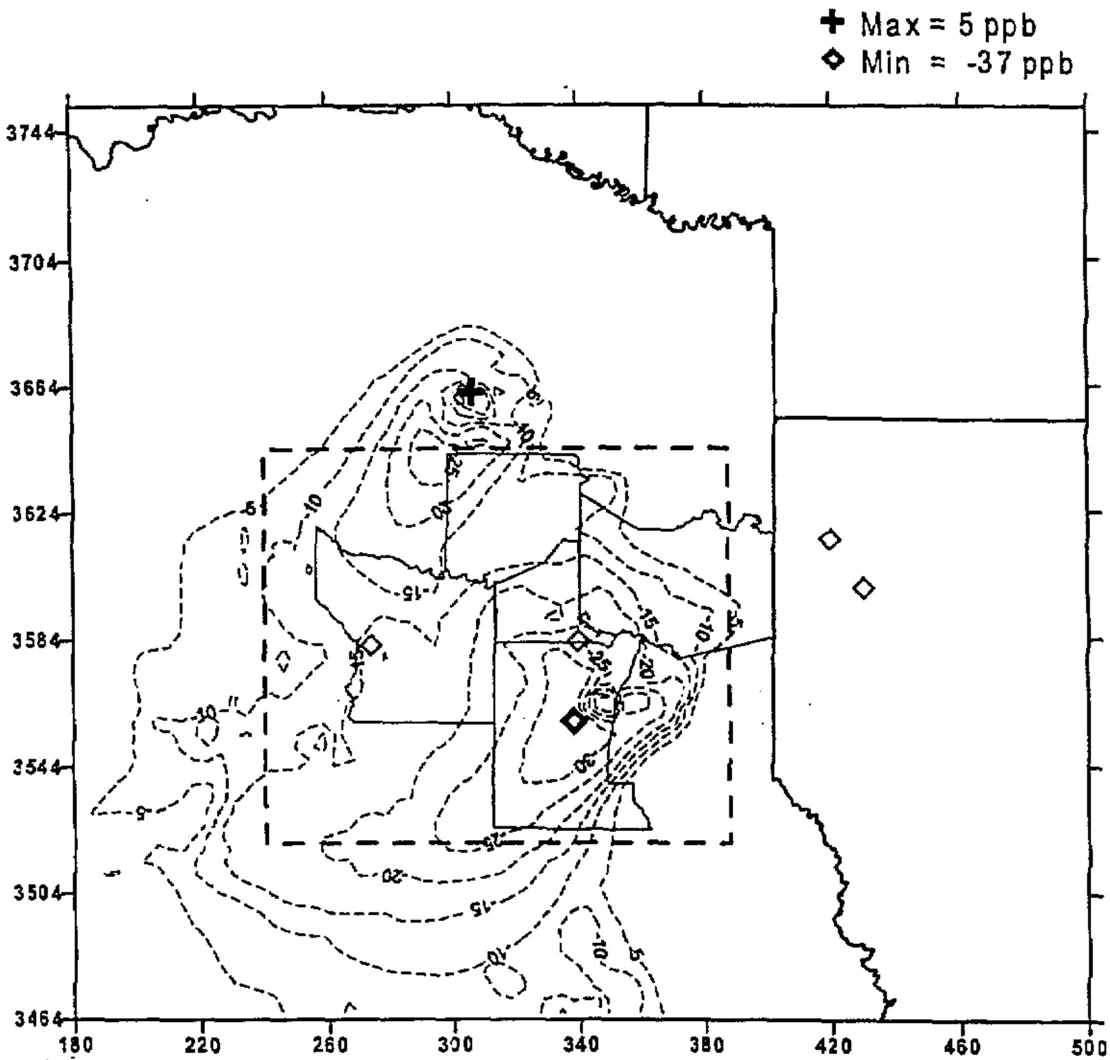
Daily Max 1-Hour Ozone (ppb)
Run = 07base 2007 Base Case
June 22, 1995

Figure 6-6(a). Daily maximum 1-hour ozone for the 2007 base case scenario for June 22, 1995.



Difference in Daily Max 1-Hour Ozone (ppb)
Control Strategy 8 - 2007 Base Case
June 22, 1995

Figure 6-6(b). Difference in daily maximum 1-hour ozone between the Cntl8 (4 km grid area) and 2007 base case scenarios for June 22, 1995. Ozone reductions due to the control strategy are shown as negative numbers by dashed lines.



Difference in Daily Max 1-Hour Ozone (ppb)
Control Strategy 10 - 2007 Base Case
June 22, 1995

Figure 6-6(c). Difference in daily maximum 1-hour ozone between the Cntl10 (17 county area) and 2007 base case scenarios for June 22, 1995. Ozone reductions due to the control strategy are shown as negative numbers by dashed lines.

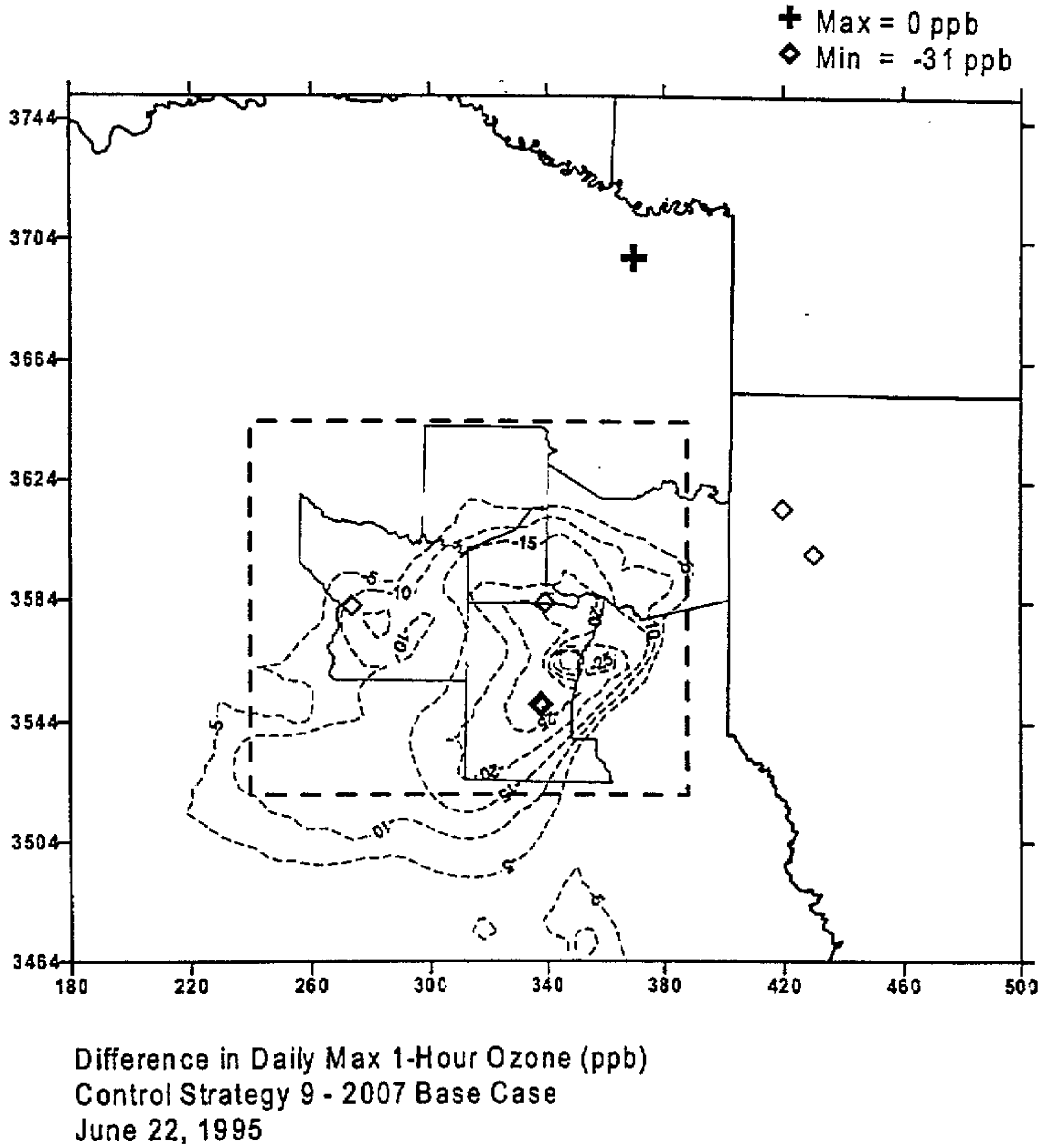


Figure 6-6(d). Difference in daily maximum 1-hour ozone between the Cntl9 (5 county area) and 2007 base case scenarios for June 22, 1995. Ozone reductions due to the control strategy are shown as negative numbers by dashed lines.

Conclusions from Round 2

The main conclusions from the analyses described above are as follows.

Controls on Major Point Sources

Point source NOx reductions are effective in reducing 1-hour ozone for across the board reductions of up to 50%. Across the board reductions between 50 and 70% show further benefits for 3 modeling days (June 22 and 23, 1995 and July 17, 1997) but disbenefits for July 16, 1997. The disbenefits for July 16 are important to the design of 1-hour ozone control strategies because they raise ozone levels above 125 ppb. The disbenefits for July 16 are highly localized to the vicinity of the Texas Eastman plant.

Controls on Mobile and Other Sources

The benefits of reducing NOx emissions from mobile and other sources are slightly greater when the starting point is Cntl4 (with a 50% NOx reduction from point sources) rather than the base case. In other words, as overall NOx levels are reduced, additional controls on NOx sources become slightly more effective. However, controls on these sources remain less effective than controls on major point sources with respect to demonstrating attainment of the 1-hour ozone standard. The impact of 30% reductions in mobile and other NOx emissions is essentially additive.

Geographic Area of Controls

The impact of the geographic area of controls has been investigated for "50/30/30" percent reductions from point, mobile and other sources, respectively. The geographic areas considered were the 4km domain, 17 counties and 5 counties (see Table 6-4 for the definitions of areas). Shrinking the area over which controls are applied produces a corresponding shrinkage in the area over which benefits occur. However, focussing on the area where base case ozone exceeded 124 ppb inside the 5 counties (south of Longview in Figure 6-6(a) shows that most of the ozone reductions in this area come from emission reductions in the 5 county area. Ozone in this area will be most responsive to NOx sources in the immediate vicinity (see Figure 6-2), namely the CSW Knox Lee, CSW Pirkey, Texas Eastman and TXU Martin Lake facilities.

ROUND 3 CONTROL STRATEGIES

The emission control strategies to be evaluated in Round 3 were selected by the NETAC Technical Committee at the meeting held on September 21, 1999. In selecting the Round 3 strategies, NETAC considered the results of the ten strategies previously evaluated in Rounds 1 and 2 which were summarized above. The Round 3 strategies are summarized as follows.

Strategy 11: Revised 2007 Base Case

The 2007 base case was revised to include the estimated impacts of Federal control programs that can reasonably be expected to be in place by 2007. The base case had also 30% lower biogenic emissions since these appeared to be over estimated. The Federal programs included were:

- Tier2 vehicles and fuels. Tier2 cars and trucks will have tighter emission standards than NLEVs and will begin phase-in with the 2004 model year. These vehicles are expected to be accompanied by a low sulfur fuel that would supercede a Texas clean gasoline such as TCAS fuel discussed below.
- 2004 Heavy Duty Diesel standards. Tighter emission standards for heavy duty diesel trucks will begin in 2004.
- New locomotive emission standards. Tighter emission standards for railway locomotives began in 1998.
- Emissions for control strategy 11 are discussed in Section 4 under the heading "Revised 2007 Base Case".

Strategy 12: Strategy 11 plus *Local Commitments*

Three local industries (Central and Southwest Services, Texas Eastman and Texas Utilities) have proposed reductions in NOx emissions at their facilities in the NETAC area. The level of these emissions reductions is described below. Strategy 12 looks at the impact of these reductions on top of the revised 2007 base case (Strategy 11).

The following summaries of the emission reduction projects and their expected impacts are based on information provided to NETAC on or about October 1, 1999.

<u>Central and Southwest Services</u>

CSW considered NOx reduction projects over the next two years that are either currently in progress or are projected to be funded next year. The following are CSW's best estimates of the percent reductions from the 1997 base line. The estimates are based on past projects and vendor information so, unfortunately, cannot be exact projections.

Fall 1999 Projects

Wilkes #2 - Burner project - expect a 25% reduction from the 1997 inventory.
Welsh #1 - Burner project - not enough information at this time to estimate the total reduction.

Fall 2000 Projects

Wilkes #3 - Burner project - expect a 25% reduction from the 1997 inventory.
Knox Lee #5 -Burner project - expect a 20% reduction from the1997 inventory.
Pirkey - Burner Project - expect a 10% reduction from the 1997 inventory.

The reductions from 1997 levels due to these measures are 12% for Knox Lee, 10% for Pirkey, and 22% for Wilkes.

Texas Eastman

There are several completed and proposed projects that Eastman Chemical Company feels confident enough to include in the future case reductions run discussed at the September 21, 1999 NETAC meeting. These are associated with the FAR agreement, and Grandfathered Permitting (SB766). They are;

1. The replacement of a cooling tower natural gas engine drive with an electric motor. FAR; Completed.
2. The installation of clean burn technology on a compressor engine. FAR; Completed.
3. Shut down of two coal fired boilers. Permitted; Anticipated in 2001 as part of the Cogen project.
4. The switching of two natural gas boilers to primarily back-up service. Permitted; anticipated in 2001 as part of the Cogen project.
5. The switching of two auxiliary boilers to primarily back-up service. Permitted; Anticipated in 2001 as part of the Cogen project.
6. Shut down of three process boilers. Grandfathered; Anticipated in January 2000 in Olefins Hydration.
7. Shut down of five natural gas compressor engines. Grandfathered; Anticipated in January 2000 in Olefins Hydration.
8. The installation of clean burn technology on five compressor engines. Grandfathered; anticipated 2001-2005.
9. The installation of clean burn technology on a cooling tower drives. Grandfathered; anticipated 2001-2005.

The uncompleted items are subject to change. Items 3-5 are currently in the process of obtaining a constructions permit and has the potential of being slowed or even cancelled due to a contested case hearing request. Items 6 and 7 are part of a realignment of the Texas Eastman ethanol business. In the event Texas Eastman doesn't shut down these sources, they will obtain a VERP for these sources. Items 8 and 9 are estimates of what will be required to obtain a VERP for these sources. The actual strategy of obtaining a VERP has not been fully evaluated due to the fact that the regulations associated with this initiative have not been promulgated. Additional reductions will likely be realized by the VERP process. They may include other technology than clean burn technology.

Taken together, these emission measures provide a 38% reduction relative to Texas Eastman's 1997 emission levels.

Texas Utilities

As agreed at the last NETAC meeting, TXU provided best estimates at this time of reductions anticipated on units in East Texas. These reductions will be achieved by lowering all the Martin Lake and Monticello units to a NOx emission rate of 0.2 pounds per million Btu. The following reductions are anticipated relative to 1997 levels:

Martin Lake 1: 40% reduction
Martin Lake 2: 33% reduction
Martin Lake 3: 45% reduction
Monticello 1: 30% reduction
Monticello 2: 32% reduction
Monticello 3: 16% reduction
Stryker Creek 1: 50% reduction

The reductions from 1997 levels due to these measures are 40% at Martin Lake, 26% at Monticello, and 31% at Stryker Creek.

Strategy 13: "TCAS" Cleaner Burning Gasoline

The TNRCC has developed a rule requiring a cleaner burning gasoline in East Texas, which is referred to here as "TCAS" gasoline. Control strategy 13 evaluates the impact of this fuel relative to the current fuel being sold in East Texas. Control strategy 13 is built on top of the original 2007 base case rather than the revised base case (strategy 11): this is because strategy 11 includes Tier 2 vehicles which could not be used with TCAS gasoline. The main practical implication of this assumption is that strategy 13 did not have reduced biogenic emissions. This will tend to overstate the benefits of the TCAS gasoline, and so is a "conservative" assumption.

TCAS gasoline has an RVP cap of 7.8 psi and a fuel sulfur limit of 150 ppm. The emissions reductions due to these limits were estimated relative to fuel currently sold in East Texas. The current fuel was characterized from a recent (1995) NIPER survey for the area. This showed that current gasoline has an average RVP of 8.3 psi and a sulfur content of 158 ppm. The emission reductions were estimated using the EPA COMPLEX model for current technology vehicles, and from the results of a recent CRC study for NLEV vehicles. The main difference between the CRC study and the COMPLEX model is that the CRC study shows that NOx emissions are reduced more by sulfur reductions with NLEVs than current technology vehicles. For 2007, we estimate that 27% of the NOx emissions from light duty vehicles will be from NLEVs with the balance (73%) coming from older technology vehicles.

The reductions in fleet average emissions due to TCAS gasoline for 2007 were estimated to be:

NOx: 0.55%
VOC: 5.4%
CO: 1.1%

These emission reductions were applied to the on road mobile emissions for the portion of the 4 km grid that is in Texas.

The emission reductions estimated here are smaller than those reported previously by the TNRCC for TCAS gasoline. In particular, the NOx effect is much smaller than the 4.5% reduction reported by the TNRCC. The main reason for this difference is the sulfur level assumed for current gasoline – since the NOx emissions reduction is mainly related to fuel sulfur reduction. We assumed a sulfur level for current fuel of 158 ppm based on 1995 fuel survey data, whereas we understand that the TNRCC assumed a current fuel sulfur level of about 330 ppm based on the default assumptions in the national level MOBILE5 model from EPA.

Ozone Reductions

The daily maximum 1-hour ozone concentrations for these strategies 11-13 are summarized in Table 6-7.

Table 6-7. Daily maximum 1-hour ozone values (ppb). Values exceeding the level of the 1-hour ozone standard are in bold.

	6/22/95	6/23/95	7/16/97	7/17/97
Longview				
07base	**133**	**127**	110	103
Control 11	124	121	102	98
Control 12	115	111	96	94
Control 13	**133**	**127**	110	103
Tyler				
07base	85	85	83	116
Control 11	82	83	79	109
Control 12	81	80	79	101
Control 13	85	85	83	116
East Texas subdomain				
07base	**145**	**144**	121	123
Control 11	**132**	**136**	111	115
Control 12	121	118	114	109
Control 13	**145**	**144**	121	123

Impact of Local Commitments

The impact of the local commitments in Control Strategy 12 can be seen by comparing the peak ozone for Control 12 against Control 11 (Table 6-7). Control 11 is the revised 2007 base case, and it has 1-hour peak ozone greater than 124 ppb for the East Texas subdomain peak on June 22 (132 ppb) and June 23 (136 ppb). The local commitments reduce these values below the level of the standard to 121 ppb on June 22 and 118 ppb on June 23. Thus, Control strategy 12 passes the 1-hour ozone attainment test.

Some Round 2 control strategies showed significant increases in peak 1-hour ozone for July 16 (ozone disbenefits). Control strategy 12 shows a small disbenefit for the East Texas subdomain peak on July 16 (an increase from 111 to 114 ppb) but this does not cause Control strategy 12 to fail attainment test.

Impact of TCAS Gasoline

The impact of the TCAS gasoline can be seen by comparing the peak ozone for Control 13 against the 2007 base case (07base) in Table 6-7. To the nearest ppb, TCAS gasoline has no impact on the daily maximum 1-hour ozone at any monitor on any day. Looking more closely reveals that there are very small ozone benefits of up to 0.2 ppb, depending upon the day (Table 6-8). This lack of impact is consistent with the small reduction in mobile source NOx emissions due to TCAS gasoline estimated above (0.55% reduction). No isopleth difference plots are included for Control 13 minus the base case because the plots are all blank (no discernible impacts).

Table 6-8. Maximum reductions in daily maximum ozone (ppb) due to TCAS gasoline anywhere in the 4 km grid. Impacts are estimated for a 2007.

Day	Ozone Reduction (ppb)
June 22	0.2
June 23	0.1
July 16	0.1
July 17	0.2

Summary of Round 3

Control strategy 12 adds local commitments (emission reductions from CSW, Texas Eastman and TXU) to the revised base case. The highest modeled ozone concentration in east Texas with Control 12 is 121 ppb, which is below the level of the 1-hour standard (125 ppb). Thus, Control 12 shows attainment of the 1-hour ozone standard.

The impacts of TCAS gasoline were modeled in control strategy 13. To the nearest ppb, TCAS gasoline has no impact on the daily maximum 1-hour ozone in East Texas. Looking more closely reveals that there are very small ozone benefits of up to 0.2 ppb. This lack of impact is consistent with the small reduction in mobile source NOx emissions (0.55% reduction) due to TCAS gasoline.

ROUND 4 CONTROL STRATEGIES

The emission control strategies evaluated in Round 4 were selected by the NETAC Technical Committee at the conference call held on October 19, 1999. Two issues were addressed in Round 4, as discussed below. Due to the nature of these issues, two strategy runs were used to re-do base cases and two strategy runs were used to look at emission reductions. The Round 4 runs completed the modeling performed for the 1998/99 biennium.

Biogenic Emissions

After evaluating the biogenic emission inventory, NETAC decided in Round 3 to proceed with modeling runs where biogenic emissions were reduced by 30%. This decision was discussed with EPA and TNRCC representatives, and they concurred. ENVIRON was just completing a project for TNRCC to update the Globeis biogenic emissions model, as described in Section 4. Using Globeis2 reduces biogenic isoprene emissions by about 30% on average for the East Texas area. Since Globeis2 is the most up-to-date biogenic emissions model available, NETAC decided to go ahead and re-evaluate ozone model performance and control strategy effectiveness using Globeis2 biogenic emissions. This entailed re-running the base year and 2007 base cases, and running the final 2007 emission reduction package (discussed below). There was general agreement among NETAC members and the TNRCC/EPA modeling representatives that biogenic emissions based on Globeis2 are more technically defensible than biogenic emissions from Globeis1/BEIS2 scaled down by 30%. The final control strategy was also evaluated with Globeis1/BEIS2 emissions scaled down by 30% to provide consistency with the Round 3 results.

Revised Emission Reductions due to Local Commitments

In Round 3, a control strategy (Control Strategy 12) was developed that combined anticipated reductions due to Federal programs with local commitments to reduce emissions from CSW, Texas Eastman and TXU. After the Round 3 model runs had been started, CSW identified an additional emissions reduction measure for the Pirkey plant:

> Pirkey - Overfire Air - expect a 20% reduction from the 1997 inventory. Spring 2003.

This is in addition to a project already considered in Control Strategy 12:

> Pirkey - Burner Project - expect a 10% reduction from the 1997 inventory. Fall 2000.

For the final control strategy evaluations in Round 4, the Pirkey "Overfire Air" project was added to the emission reductions already included in Control Strategy 12. The total reduction expected for Pirkey is 30% from 1997 levels.

Table 6-9. Summary of Round 4 model runs.

Run	Year	Biogenic Inventory	Emission Reductions
Cntl14, also called Base 2	Base year (1995/1997)	Globeis2	None
Cntl15	2007	Globeis2	Federal reductions
Cntl16	2007	Globeis2	Federal reductions plus revised local commitments
Cntl17	2007	Globeis1/BEIS2 scaled down by 30%	Federal reductions plus revised local commitments

Control Strategy 14

Control strategy 14 was used to re-run the base year base case with Globeis2 biogenic emissions and these results were discussed in Section 5. Base Case 2 was the final base year base case.

Control Strategy Impacts

The impact of the revised control strategy on 2007 maximum 1-hour ozone is compared for two biogenic emission inventories in Tables 6-10 and 6-11, for June 1995 and July 1997, respectively.

With Globeis2 biogenic emissions, the highest 1-hour ozone for the base case (Control strategy 11) 136.2 ppb on June 23. The highest 1-hour ozone for the revised control strategy with Globeis 2 was 118.6 ppb on July 16. Thus, the revised control strategy demonstrates attainment of the 1-hour ozone NAAQS with a margin of safety of nearly 6 ppb when Globeis2 emissions are used.

With the original Globeis1/BEIS2 biogenic emissions reduced by 30%, the revised control strategy reduces maximum modeled ozone levels in East Texas from 136.2 ppb on June 23 to 120.8 ppb on June 23. Thus, the revised control strategy also demonstrates attainment of the 1-hour ozone NAAQS with 30% reduced Globeis1/BEIS2 biogenic emissions.

Table 6-10. Daily maximum ozone (ppb) for the June 1995 episode future year base cases (cntl11 and cntl15) and revised control strategy cases (cntl17 and cntl16). Values greater than 124 ppb are in bold.

	Tyler		Longview		East Texas Subdomain	
	22-June	**23-June**	**22-June**	**23-June**	**22-June**	**23-June**
Globeis1/BEIS2 reduced by 30%						
Cntl 11 - base	123.7	121.0	82.3	82.9	**132.0**	**136.2**
Cntl 17 - control	113.7	110.6	81.3	79.8	120.8	118.0
Globeis2 Biogenic Emissions						
Cntl 15 - base	117.5	122.1	83.0	84.8	**127.4**	**136.2**
Cntl 16 - control	110.0	110.6	79.7	79.5	117.6	117.7

Table 6-11. Daily maximum ozone (ppb) for the July 1997 episode future year base cases (cntl11 and cntl15) and revised control strategy cases (cntl17 and cntl16). Values greater than 124 ppb are in bold.

	Tyler		Longview		East Texas Subdomain	
	16-July	**17-July**	**16-July**	**17-July**	**16-July**	**17-July**
Globeis1/BEIS2 reduced by 30%						
Cntl 11 - base	101.8	98.2	78.8	109.2	111.4	114.8
Cntl 17 - control	95.9	92.4	78.8	100.6	113.8	108.4
Globeis2 Biogenic Emissions						
Cntl 15 - base	107.3	101.9	82.1	113.2	115.7	120.0
Cntl 16 - control	99.3	94.3	79.4	101.7	118.6	113.7

FINAL 2007 BASE CASE

The final 2007 base cases are the Round 4 model runs called control strategy 15. Daily maximum 1-hour ozone isopleth plots for the final base case are shown in Figures 6-7 through 6-14.

FINAL 2007 CONTROL STRATEGY

The final 2007 control strategies are the Round 4 model runs called control strategy 16. Daily maximum 1-hour ozone isopleth plots for the final control strategy are shown in Figures 6-7 through 6-14.

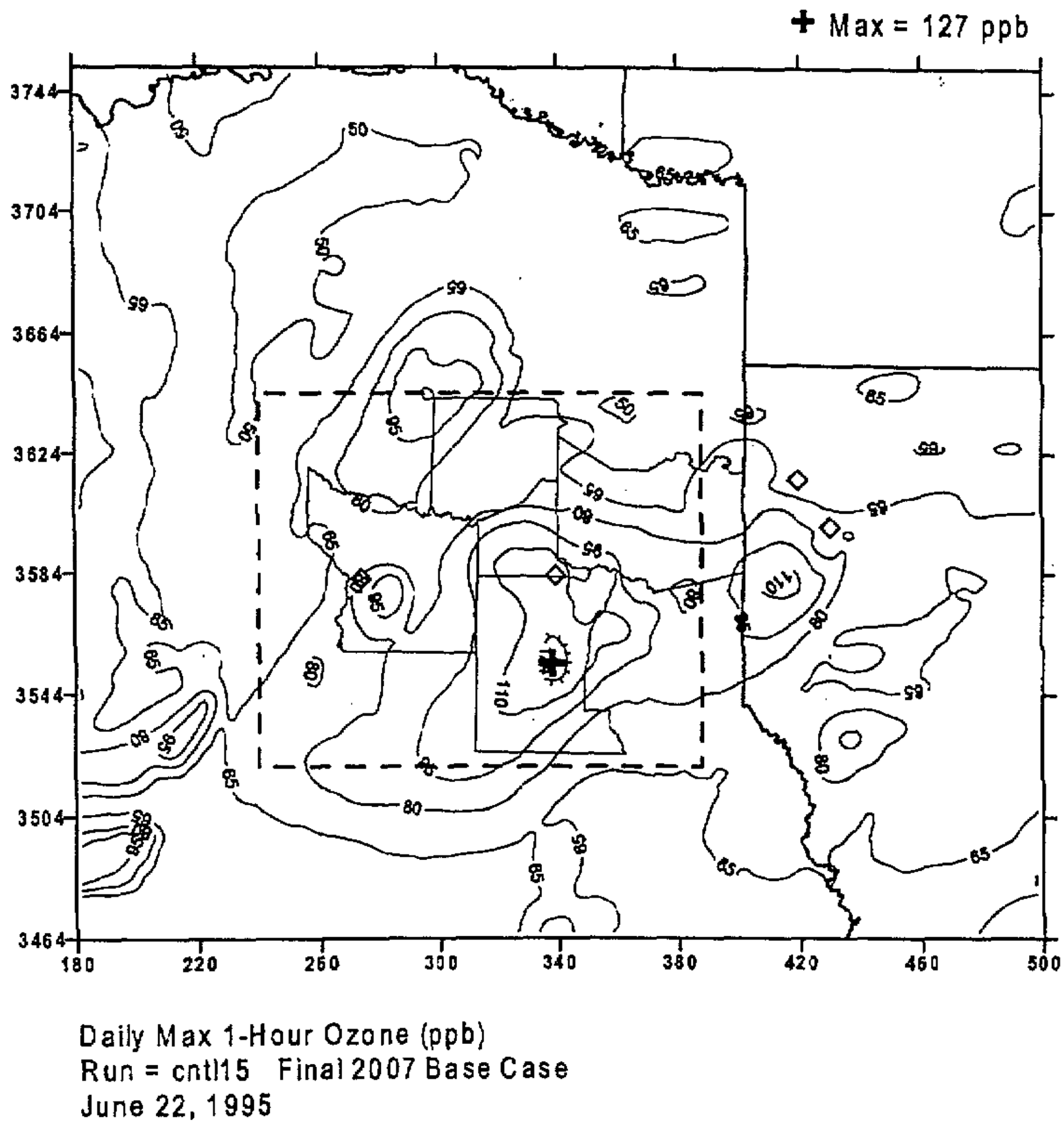


Figure 6-7. Isopleth of daily maximum 1-hour ozone for the final 2007 base case for June 22, 1995.

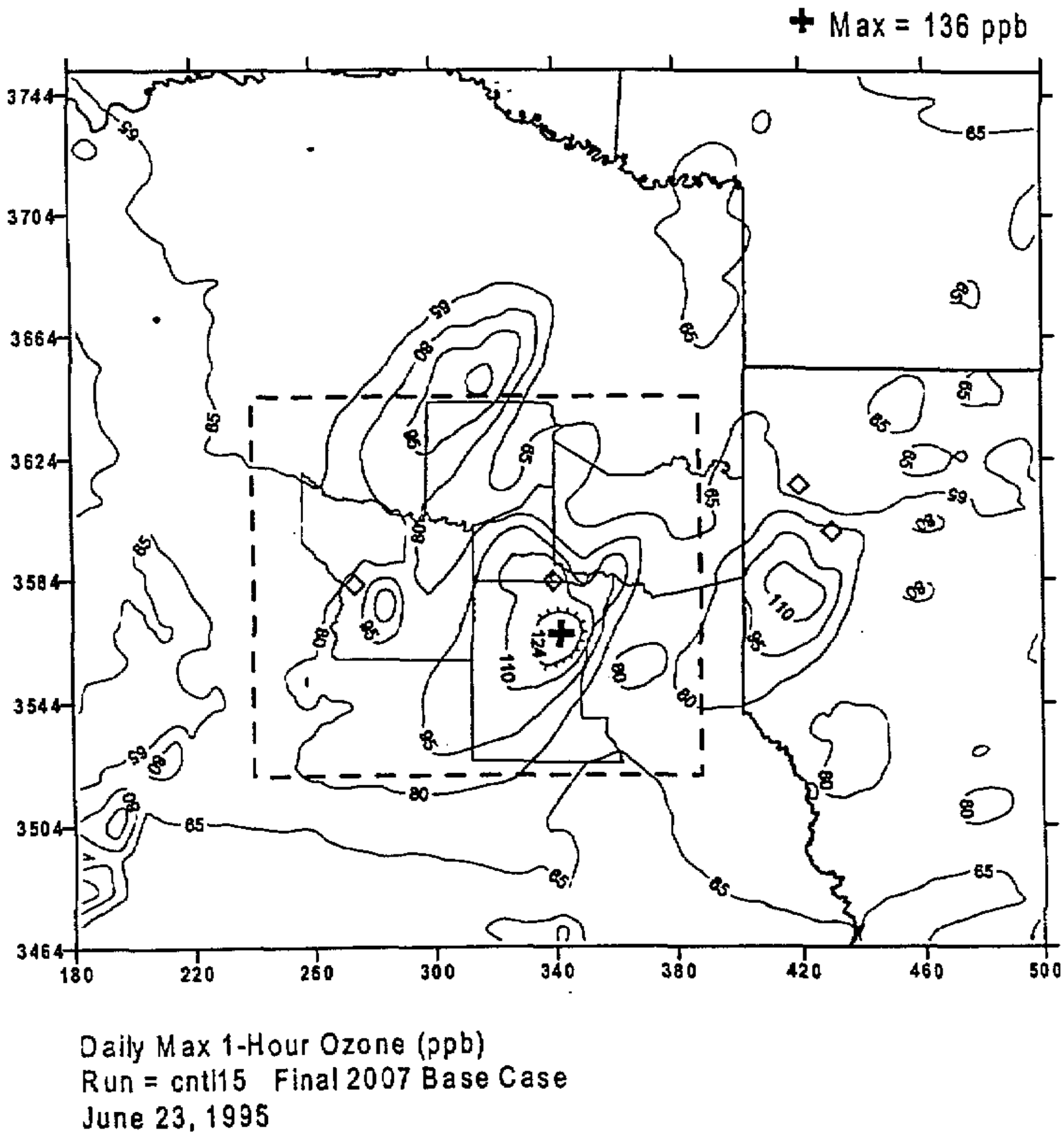


Figure 6-8. Isopleth of daily maximum 1-hour ozone for the final 2007 base case for June 23, 1995.

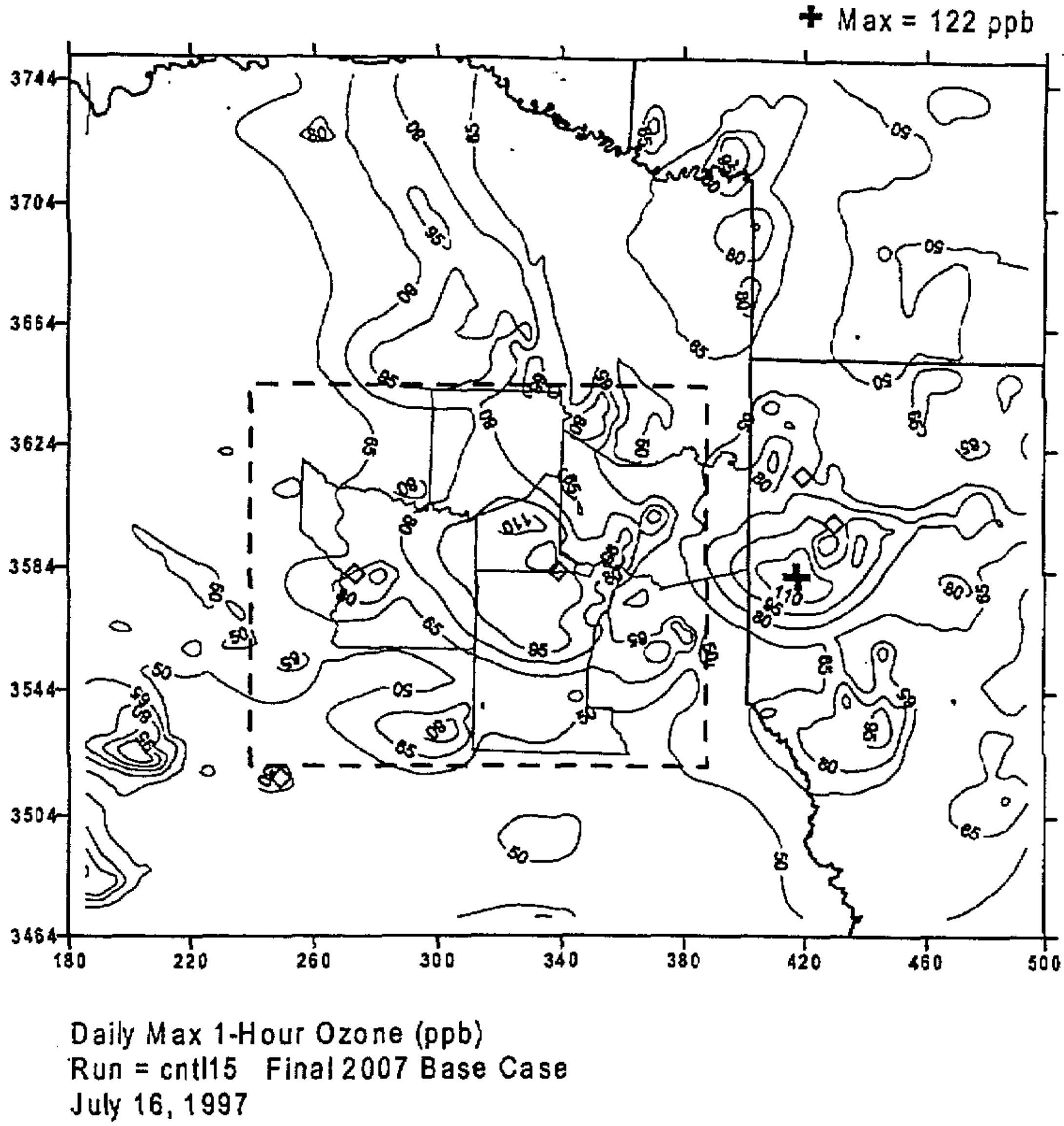


Figure 6-9. Isopleth of daily maximum 1-hour ozone for the final 2007 base case for July 16, 1997.

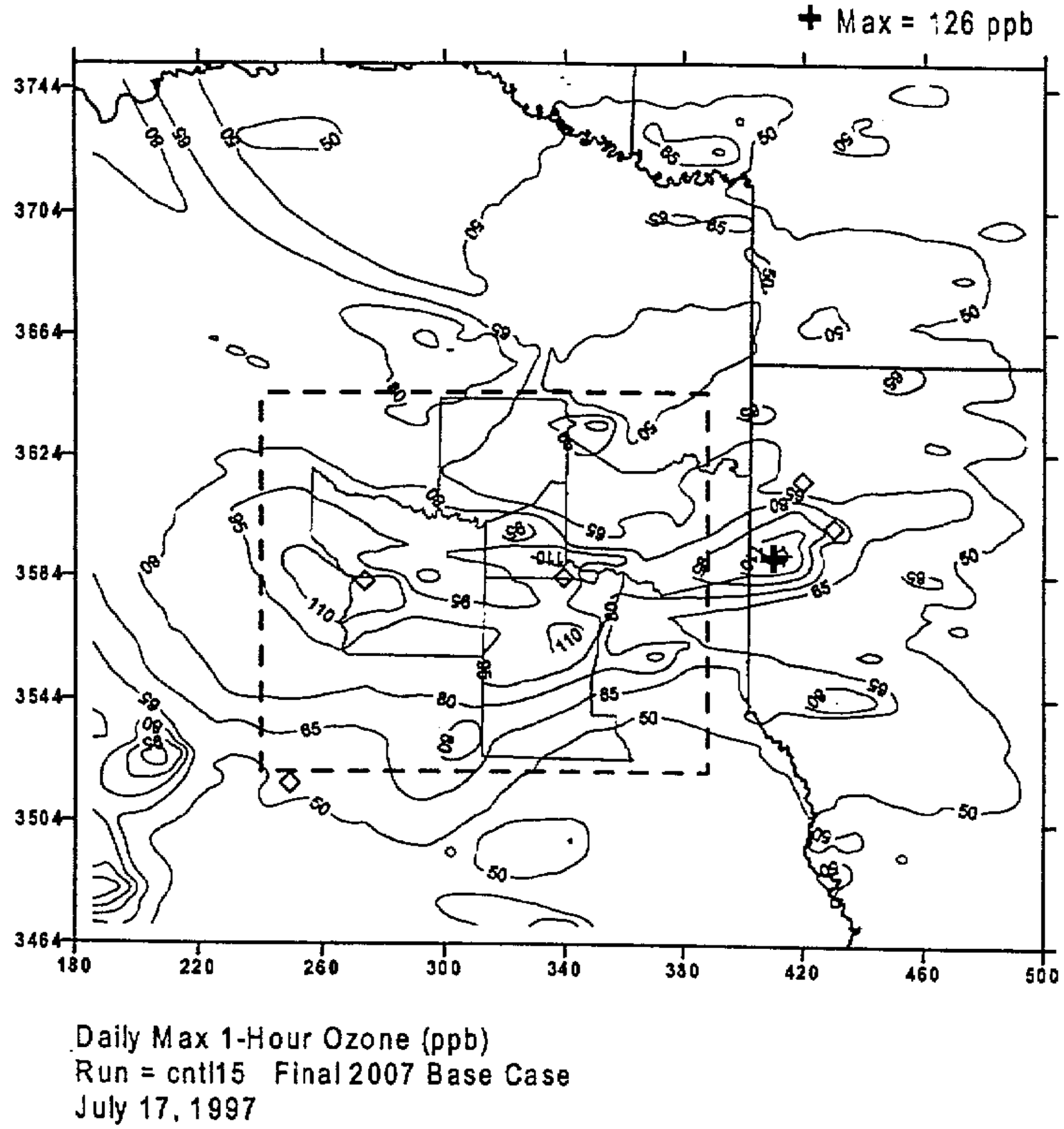


Figure 6-10. Isopleth of daily maximum 1-hour ozone for the final 2007 base case for July 17, 1997.

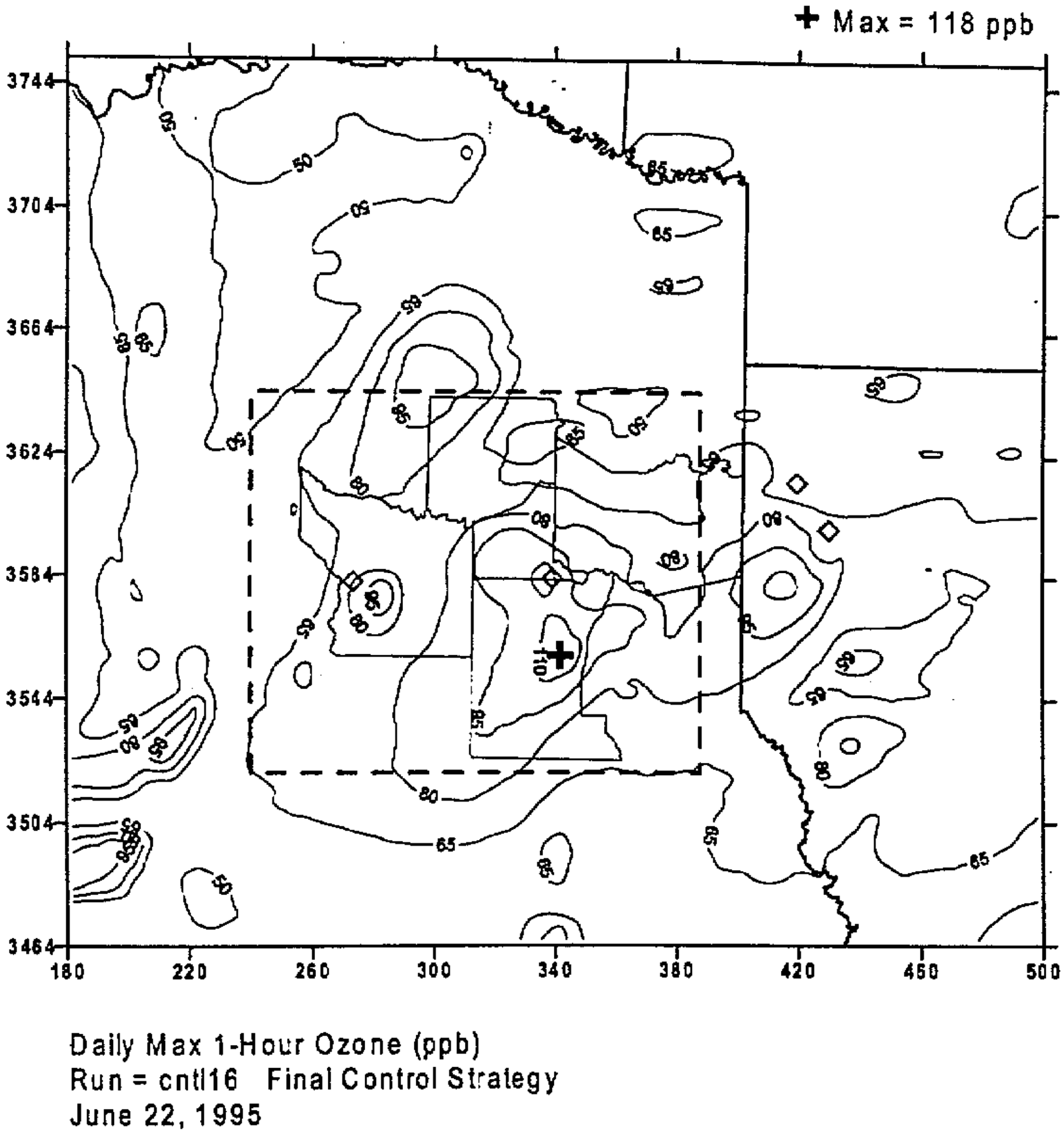


Figure 6-11. Isopleth of daily maximum 1-hour ozone for the final 2007 control strategy for June 22, 1995.

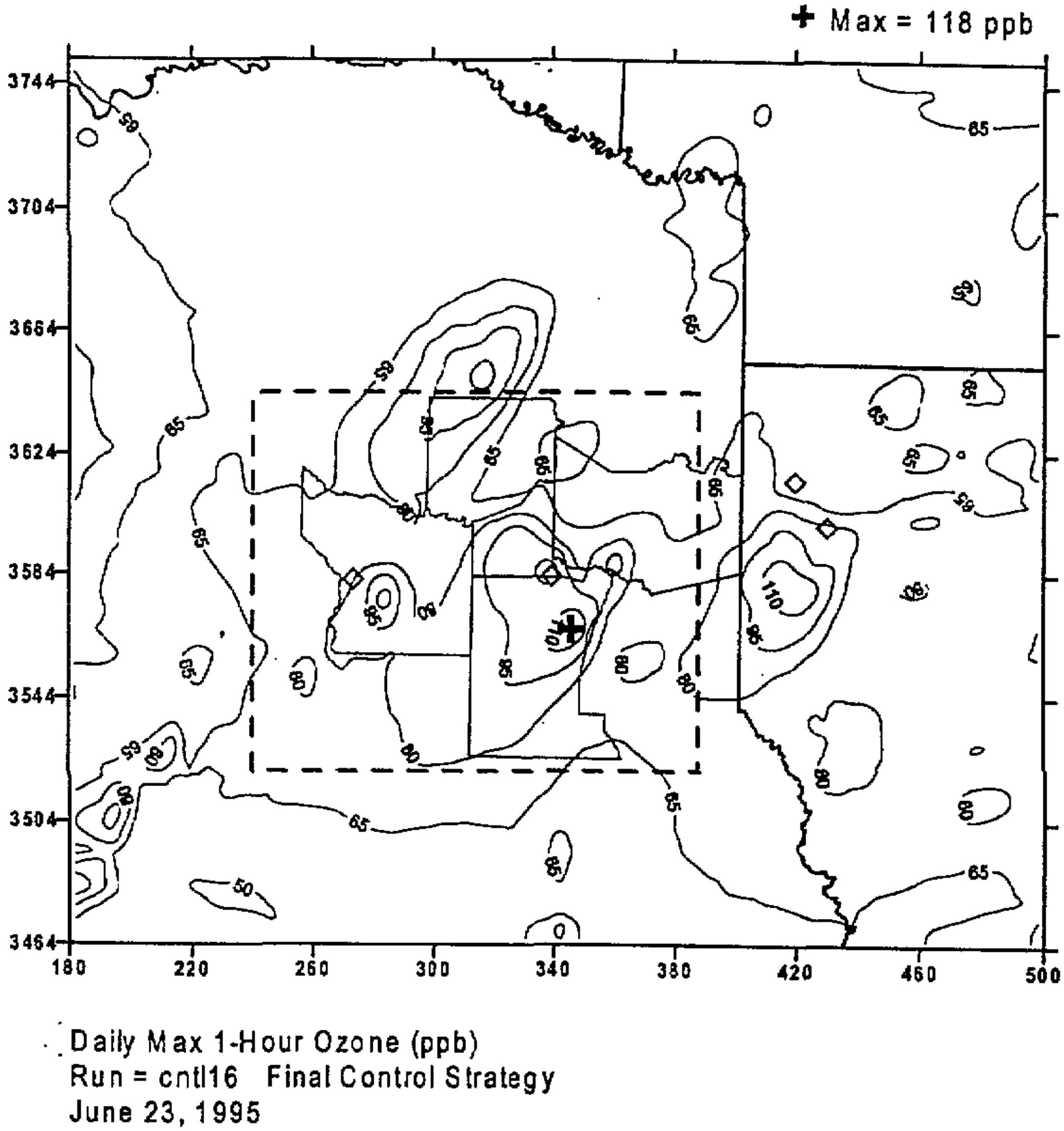
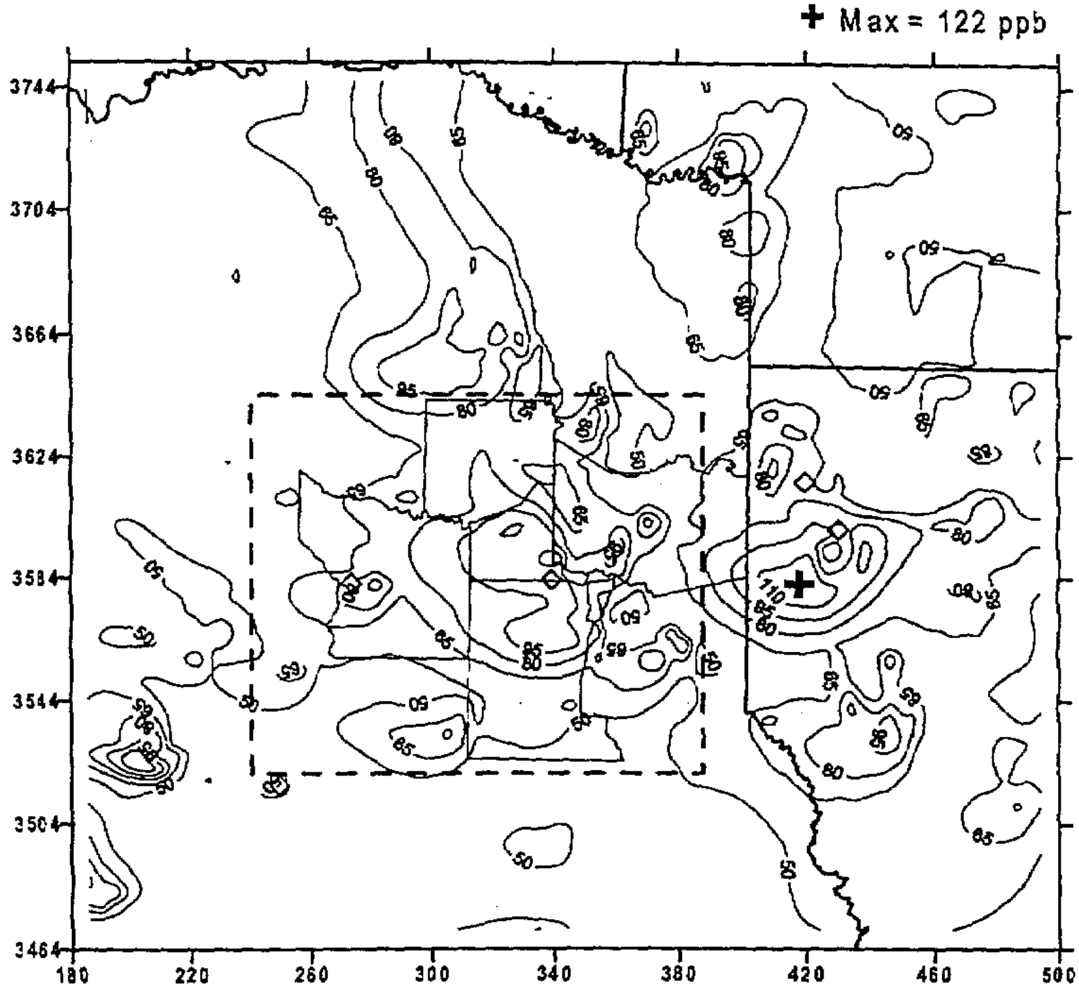
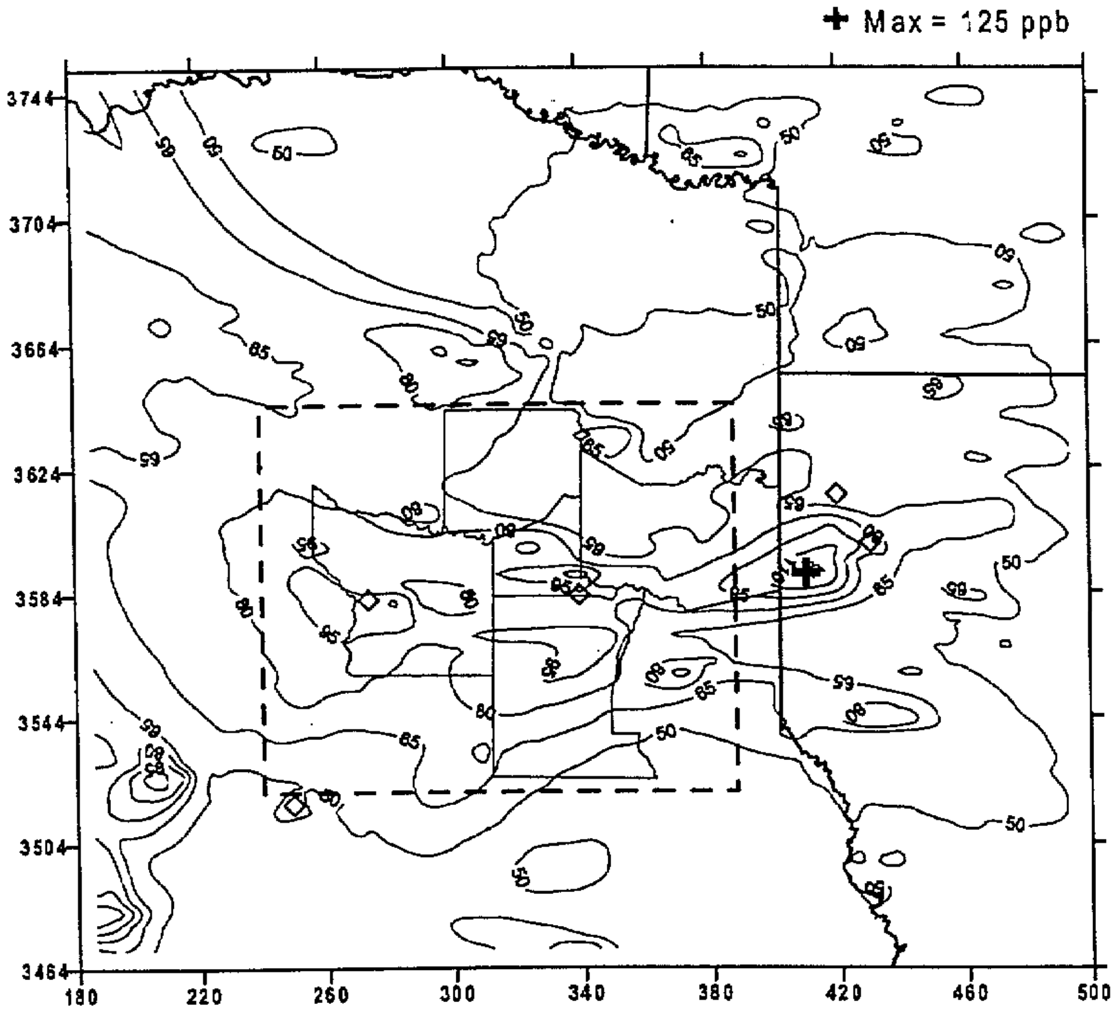


Figure 6-12. Isopleth of daily maximum 1-hour ozone for the final 2007 control strategy for June 23, 1995.



Daily Max 1-Hour Ozone (ppb)
Run = cntl16 Final 2007 Control Strategy
July 16, 1997

Figure 6-13. Isopleth of daily maximum 1-hour ozone for the final 2007 control strategy for July 16, 1997.



Daily Max 1-Hour Ozone (ppb)
Run = cntl16 Final 2007 Control Strategy
July 17, 1997

Figure 6-14. Isopleth of daily maximum 1-hour ozone for the final 2007 control strategy for July 17, 1997.

7. RESULTS FOR 8-HOUR OZONE

Impacts of control strategies on 8-hour ozone were evaluated using the methodologies described in the most recent draft EPA guidance. There are three main uncertainties with this methodology at present:

- The proposed 8-hour standard has been subject to challenge and may change.
- The methodology used to determine whether control strategies meet the 8-hour ozone standard (as proposed by EPA) is in draft form, and may change.
- The four modeling days used to develop control strategies were selected primarily with 1-hour ozone in mind and additional days will be considered in future NETAC modeling for 8-hour ozone.

ATTAINMENT DEMONSTRATION METHODOLGY

The methodology for the 8-hour ozone attainment test as described in the draft guidance distributed by David Mobley of EPA on June 21, 1999. The procedures are new and quite complex, so the EPA and TNRCC modeling representatives were asked to review the methods as we have implemented for this study before they were used to generate results.

The methodology calls for scaling base year design values (DVs) using relative reduction factors (RRFs) from a photochemical model in order to estimate future design values. The calculation is carried out for each monitor. In addition, a screening calculation is also carried out to identify grid cells with consistently high ozone. Scaled DVs are also calculated for these screened cells. The idea behind the screening cells is to account for any areas with consistently high modeled ozone that are not captured by the monitoring network. The attainment test is passed if all the future year scaled DVs are 84 ppb or less.

Figure 7-1 shows a schematic outline of the calculations and identifies the input data required to complete the calculation. These are:

1. A monitor list – the list of monitors along with base year DVs for each monitor.
2. A screening cell list – the list of cells to be considered in the screening cell calculation along with the monitors that are considered to be associated with that grid cell. This list may be a sub-set of the modeling grid covering just the area for which controls are being developed. The significance of associating monitors with each grid cell is in the selection of an appropriate base year DV for the grid cell and in setting concentration thresholds for including the grid cell in the screening calculation, discussed below. There are no firm criteria for deciding how to associate monitors with grid cells.
3. Base case ozone – gridded 8-hour daily maximum ozone for the base year.
4. Future case ozone – gridded 8-hour daily maximum ozone for the future year.

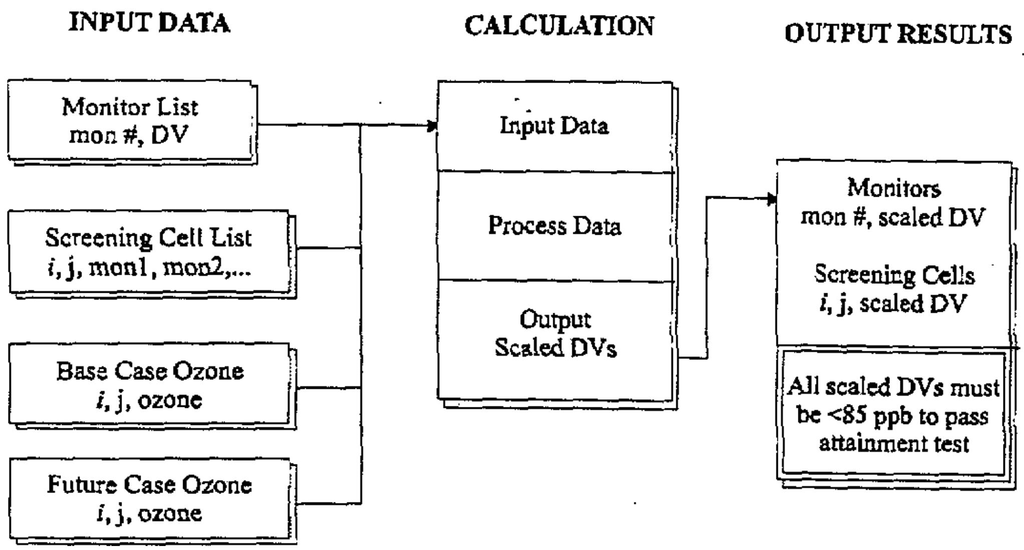


Figure 7-1. Overview of the 8-hour ozone attainment test methodology.

The details of the calculations are as follows:

- Monitor DV Scaling

1. For each monitor, find the daily maximum 8-hour ozone in an *n* x *n* block of cells around the monitor for both the base and future case. Repeat for each modeling day being used for control strategy development. For a 4 km grid, *n*=7 according to the guidance.
2. Exclude days when the base case daily maximum 8-hour ozone was below 70 ppb.
3. Average the daily maximum 8-hour ozone across days for the base and future year.
4. Calculate the RRF = (average future daily max) / (average base daily max).
5. Calculate the scaled DV = base year DV x RRF.
6. Repeat 1-5 for each monitor

- Screening Cell DV Scaling

7. For each grid cell on the screening cell list, count the number of days where the modeled daily maximum 8-hour ozone is at least 5% greater than the modeled daily maximum 8-hour ozone at any "associated" monitor, and at least 70 ppb.
8. If the number of days is 50% or greater of the total days, treat this cell as if it were a monitor – this is a "screened cell."
9. The base year DV to be used for a screened cell is the maximum of the base year DVs for any "associated" monitor.
10. Calculated the scaled DV for each screened cell as if it were a monitor (steps 1-5 above).
11. Repeat 7-10 for each grid cell on the screening cell list.

Example Results

Results are presented in Table 7-1 using the preliminary base case (base1) and 2007 base case as an example.

Table 7-1. Sample results based on four modeling days.

i	j	Base (ppb)	Future (ppb)	RRF	DV	Scaled DV	Days Over
Monitor Cells							
GGGC		103.8	102.1	0.984	91	90	4
TX47		100.0	97.6	0.976	89	87	4
Screened Cells							
40	24	108.5	106.0	0.977	91	89	2
41	24	108.5	106.0	0.977	91	89	2
40	25	108.8	106.1	0.976	91	89	2
41	25	108.8	106.1	0.976	91	89	2
42	25	108.5	106.0	0.977	91	89	2
41	26	110.0	107.3	0.976	91	89	2

Scaled design values were calculated for both monitors. Data from all four days were used in the calculation of the RRF because on all 4 days the base case daily maximum 8-hour ozone exceeded 70 ppb in the 7 by 7 block of cells around each monitor. The attainment test is failed at both monitors because the scaled DV exceeds 84 ppb.

Six screened cells were identified. All occurred to the south of Longview and were "associated" with the GGGC monitor and therefore use the DV for that monitor. As expected, the average base case daily maximum 8-hour ozone for the screened cells is higher than at the associated monitor. Only 2 days exceeded the maximum ozone at the associated monitor by 5% (step 7, above). Two out of 4 days just barely meets the "50% of days" criterion in the screening cell selection (step 8, above). However, all days with base case ozone greater than 70 ppb at the screened cell were used in the calculation of the RRF for the screened cell. The RRFs for the screened cells are smaller than at the associated monitor leading to lower scaled DVs – in other words ozone decreased more between the base and future years in the screened cells that at the associated monitor. Therefore, the screened cells are not limiting in this example. However, they might become limiting for other future year control scenarios.

CONTROL STRATEGY EFFECTIVENESS

The design value scaling approach was applied for all the future year base case and control strategy runs described in Section 6. The results are shown in Table 7-2. The example calculation shown in Table 7-1, above, is the first line in Table 7-2. The following points should be noted in reading Table 7-2:

- Design value scaling was based on model results for days with acceptable 1-hour model performance, namely June 22 and 23, 1995 and July 16 and 17, 1995.

- The control strategy runs used different biogenic emission inventories and it is necessary to match each control strategy run to the base case run with the same biogenic emissions, as shown in the second column of Table 7-2.

- Base year 8-hour design values for Longview and Tyler monitors were the 1995-97 design values calculated by the TNRCC of 91 ppb and 89 ppb, respectively.

- For the screening cell calculation, the number of screened cells is given along with the highest RRF and Scaled DV.

- The "search area" for screening cells was restricted to the East Texas sub-domain as used to determine the 1-hour peak ozone over East Texas (see Figure 5-1).

- All the screened cells occurred to the south of Longview, in the area of maximum ozone concentrations on June 22 and June 23, and therefore were assigned a base year DV of 91 ppb from the Longview monitor.

Table 7-2. Design value scaling calculations for 8-hour ozone. Scaled design values of 85 ppb or greater are shown in bold.

Future Scenario	Base Year Scenario	Tyler		Longview		Screened Cells		
		RRF	Scaled DV	RRF	Scaled DV	No. of Cells	RRF Max	Scaled DV
2007 base	base1	0.976	**87**	0.984	**90**	6	0.977	**89**
Strategy 1	base1	0.931	83	0.937	**85**	6	0.894	81
Strategy 2	base1	0.945	84	0.970	**88**	6	0.966	**88**
Strategy 3	base1	0.939	84	0.961	**87**	6	0.961	**87**
Strategy 4	base1	0.896	80	0.895	81	6	0.830	76
Strategy 5	base1	0.856	76	0.844	77	6	0.756	69
Strategy 6	base1	0.859	76	0.876	80	6	0.818	74
Strategy 7	base1	0.851	76	0.861	78	6	0.811	74
Strategy 8	base1	0.809	72	0.840	76	6	0.799	73
Strategy 9	base1	0.849	76	0.872	79	6	0.841	77
Strategy 10	base1	0.825	73	0.863	79	6	0.829	75
Strategy 11	diag2	0.959	**85**	0.980	**89**	10	0.984	**90**
Strategy 12	diag2	0.941	84	0.944	**86**	10	0.922	84
Strategy 13	base1	0.975	**87**	0.984	**90**	6	0.976	**89**
Strategy 15 - Final 2007 Base Case	base2	0.972	**87**	0.978	**89**	4	0.981	**89**
Strategy 16 - Final Control Strategy	base2	0.930	83	0.933	**85**	4	0.909	83
Strategy 17	diag2	0.939	84	0.937	**85**	10	0.913	83

Both 2007 base case runs (2007 base, strategy 11 and strategy 15) show that additional (local) controls are needed for 8-hour ozone at Longview and Tyler, i.e. the scaled DVs are 85 ppb or greater.

Strategies 1 through 3 show the effectiveness of across the board 30% reductions in NOx emissions from major point (strategy 1), mobile (strategy 2) and other surface anthropogenic (strategy 3) sources. The relative effectiveness of these strategies at Longview and Tyler can be seen by comparing the RRFs. Controls on major point sources are effective at both Longview and Tyler. Controls on low level NOx emissions (mobile and other surface anthropogenic sources) are more effective at Tyler than Longview.

The response of screened cells to control strategies is generally similar to Longview. The screened cells are more responsive to point source reductions (e.g., strategies 1 and 4) than Longview. Accordingly, the screened cells have lower scaled DVs than Longview in all scenarios with the exception of strategy 11.

The final control strategy (strategy 16) passes the attainment test for Tyler and the screened cells, but not for the Longview monitor where the scaled DV is 85 ppb. This is very close to passing the attainment test (within 1 ppb) and, given the uncertainties with the 8-hour standard and attainment demonstration methodology listed at the start of Section 7, should not be a cause for concern at this time over the effectiveness of the final control strategy.

Isopleths of daily maximum 8-hour ozone are shown below, as follows:

- Final base year base case – Figures 7-2 through 7-5.
- Final 2007 base case – Figures 7-6 through 7-9.
- Final 2007 control strategy – Figures 7-10 through 7-13.

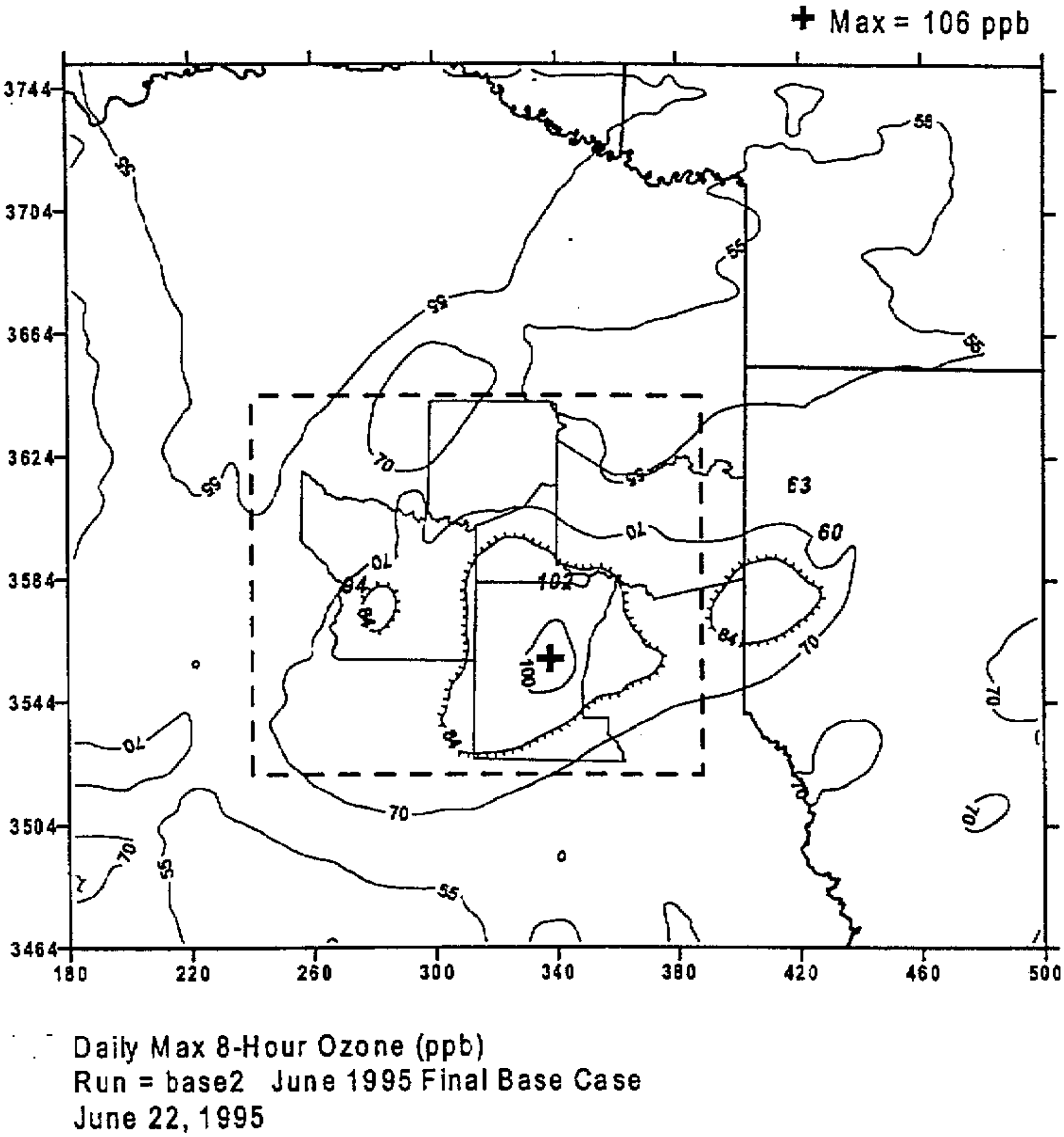


Figure 7-2. Isopleth of daily maximum 8-hour ozone for the final base case for July 22, 1995.

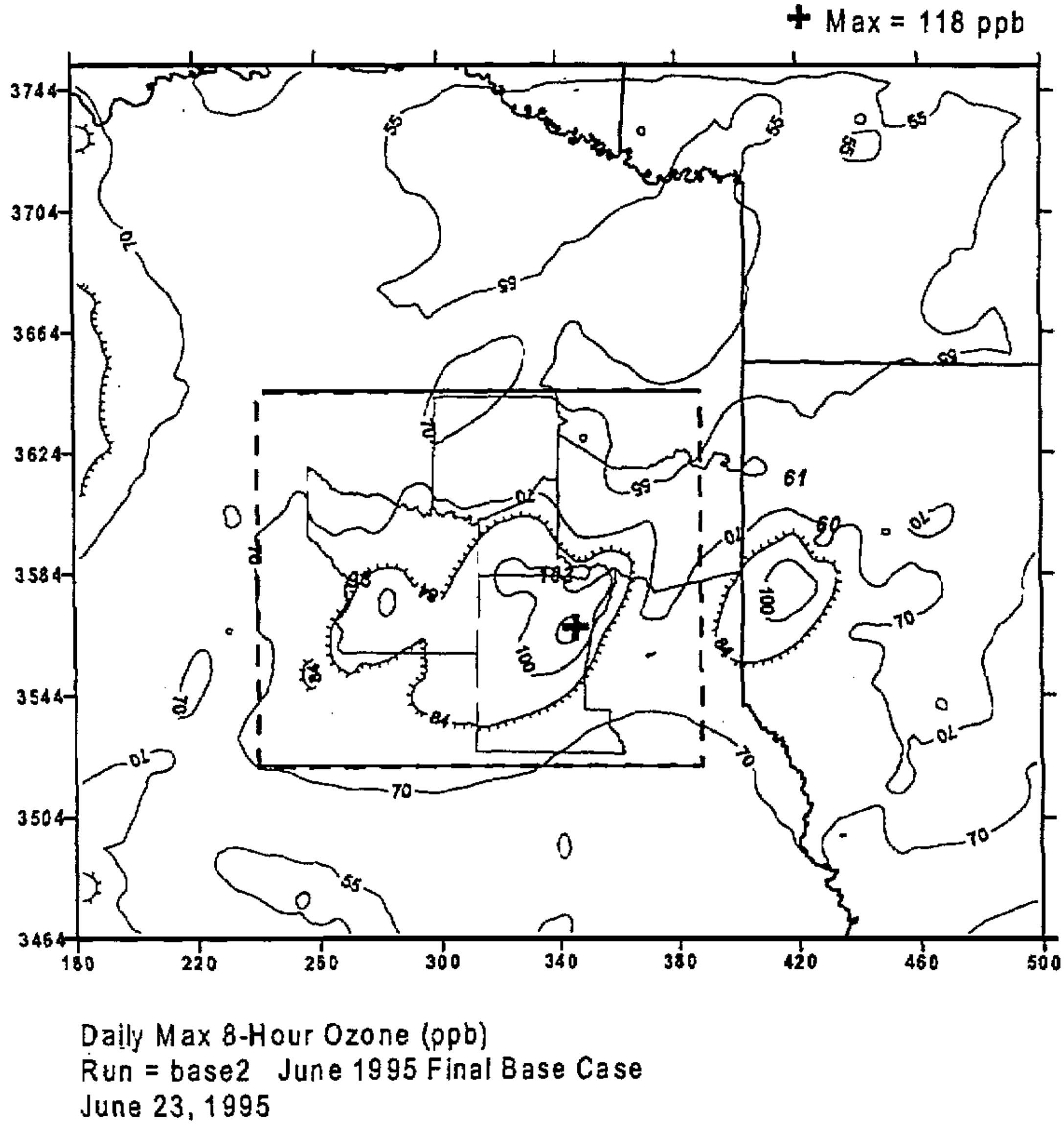


Figure 7-3. Isopleth of daily maximum 8-hour ozone for the final base case for June 23, 1995.

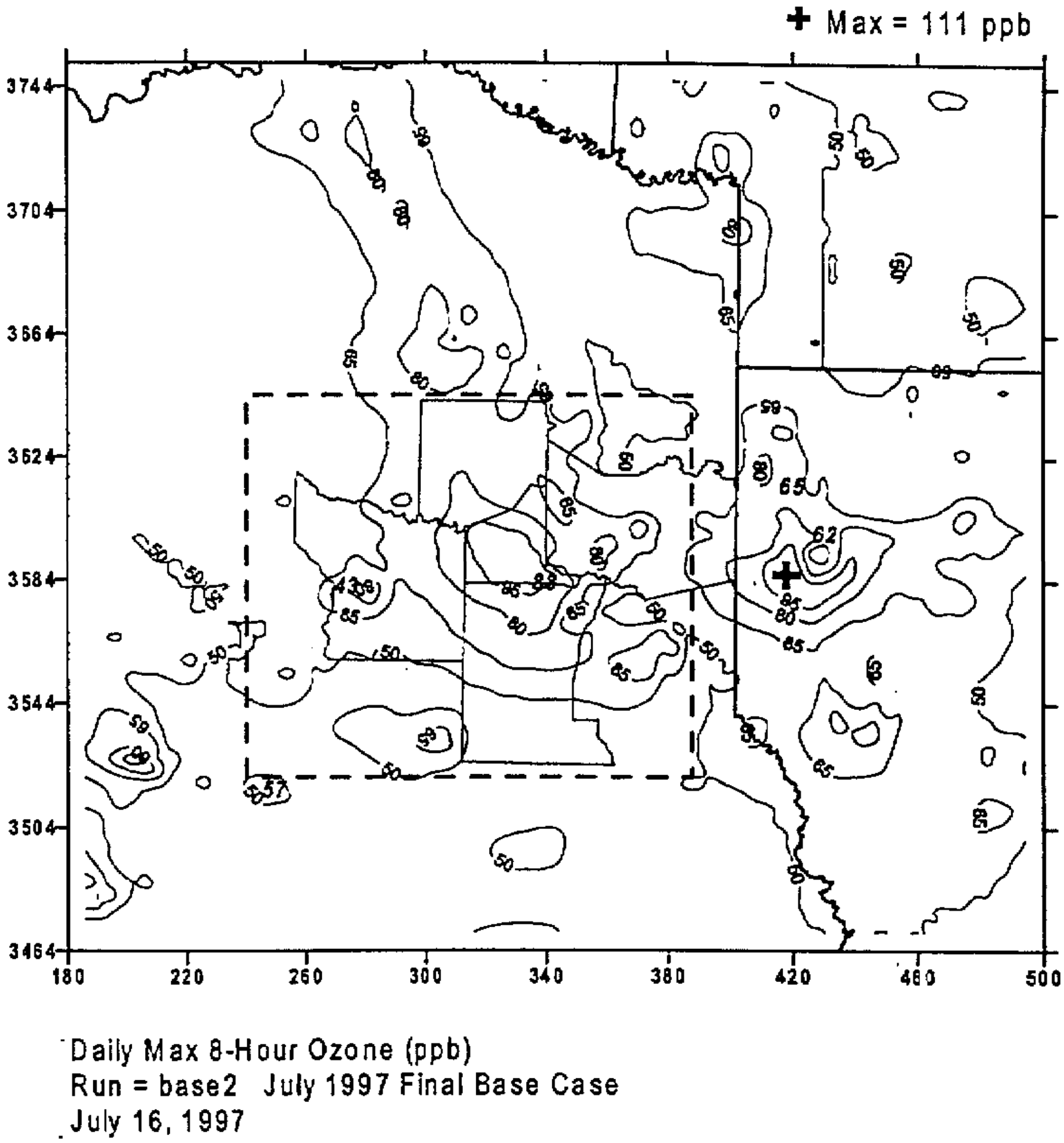


Figure 7-4. Isopleth of daily maximum 8-hour ozone for the final base case for July 16, 1997.

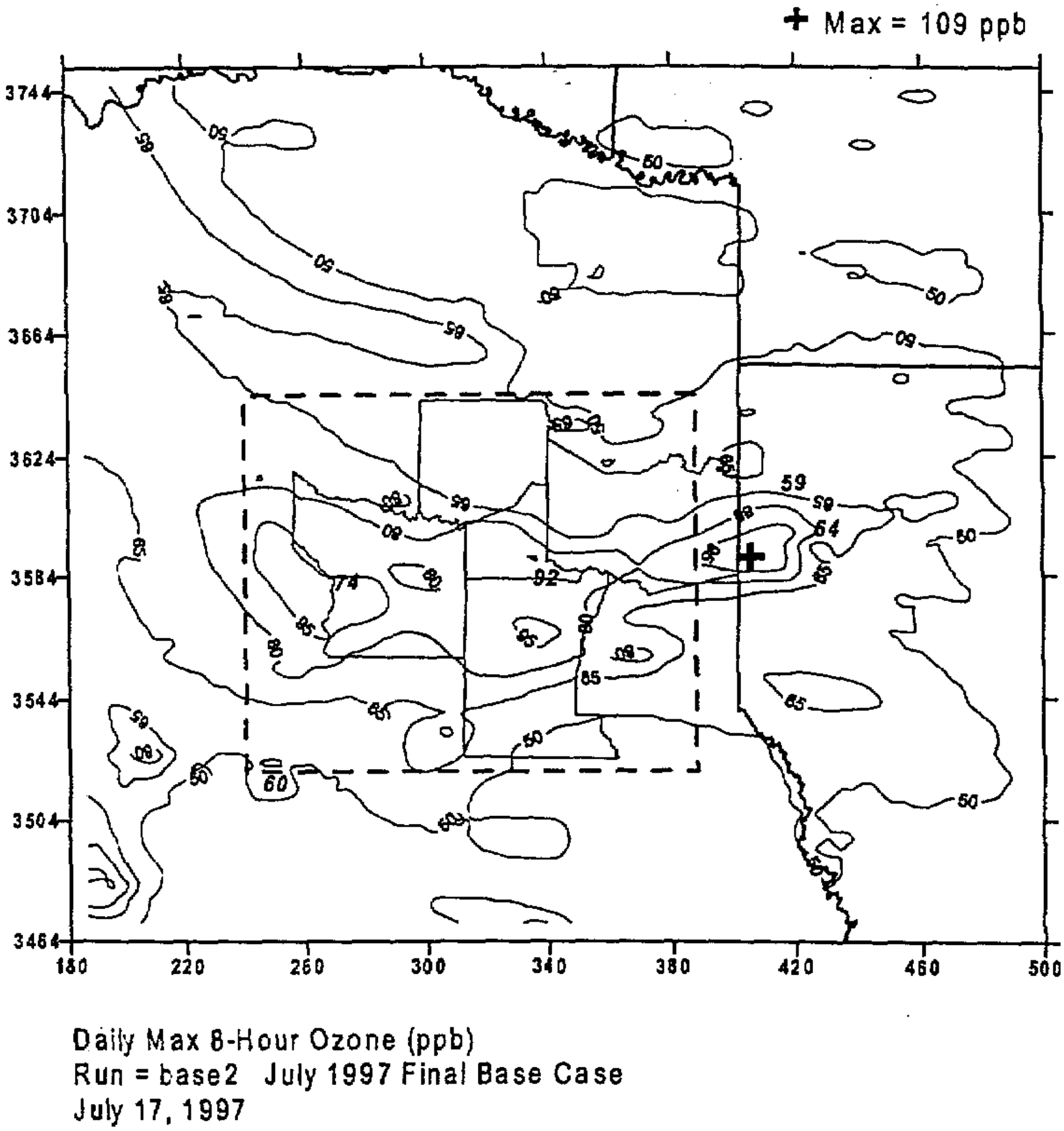


Figure 7-5. Isopleth of daily maximum 8-hour ozone for the final base case for July 17, 1997.

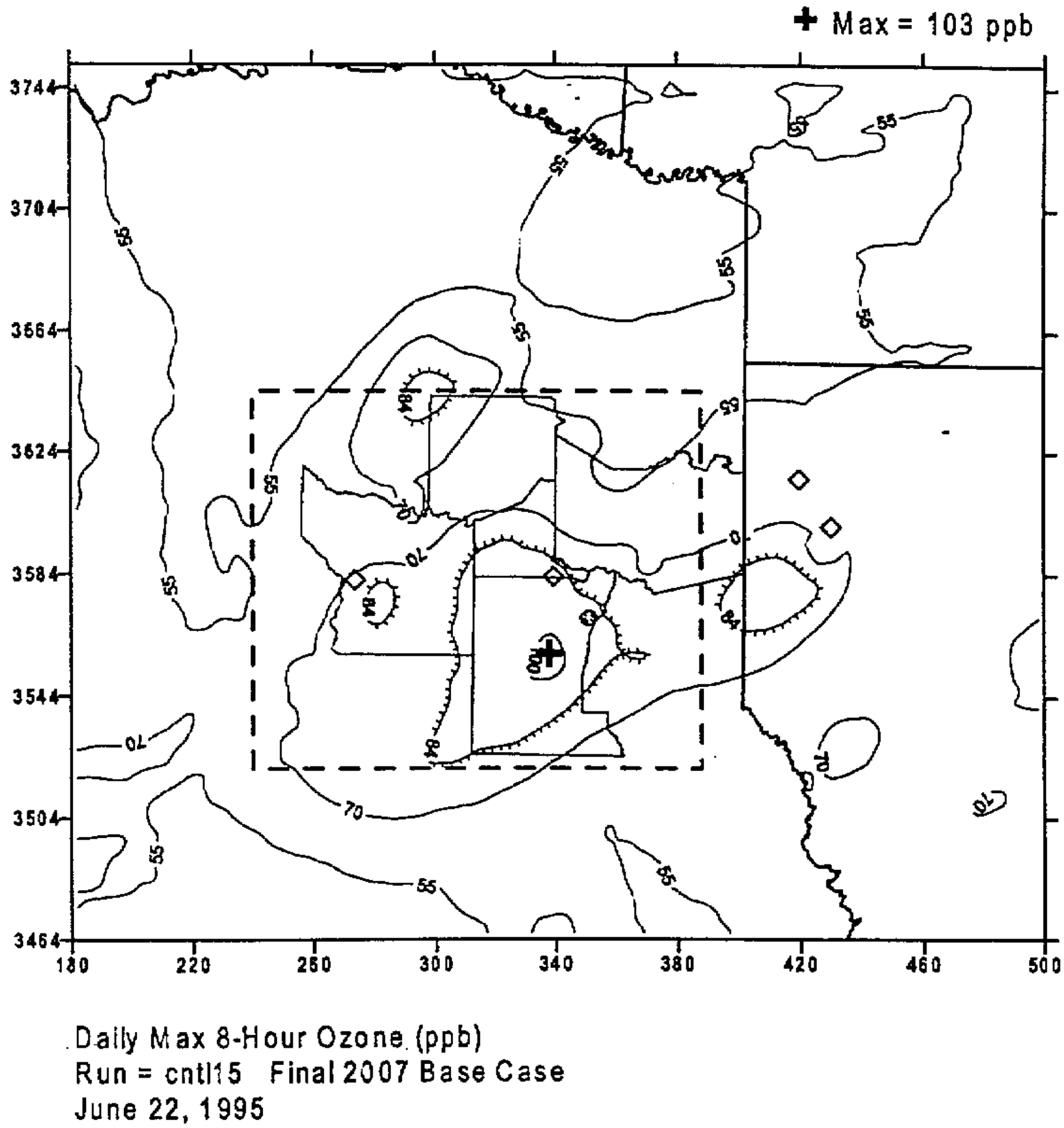


Figure 7-6. Isopleth of daily maximum 8-hour ozone for the final 2007 base case for July 22, 1995.

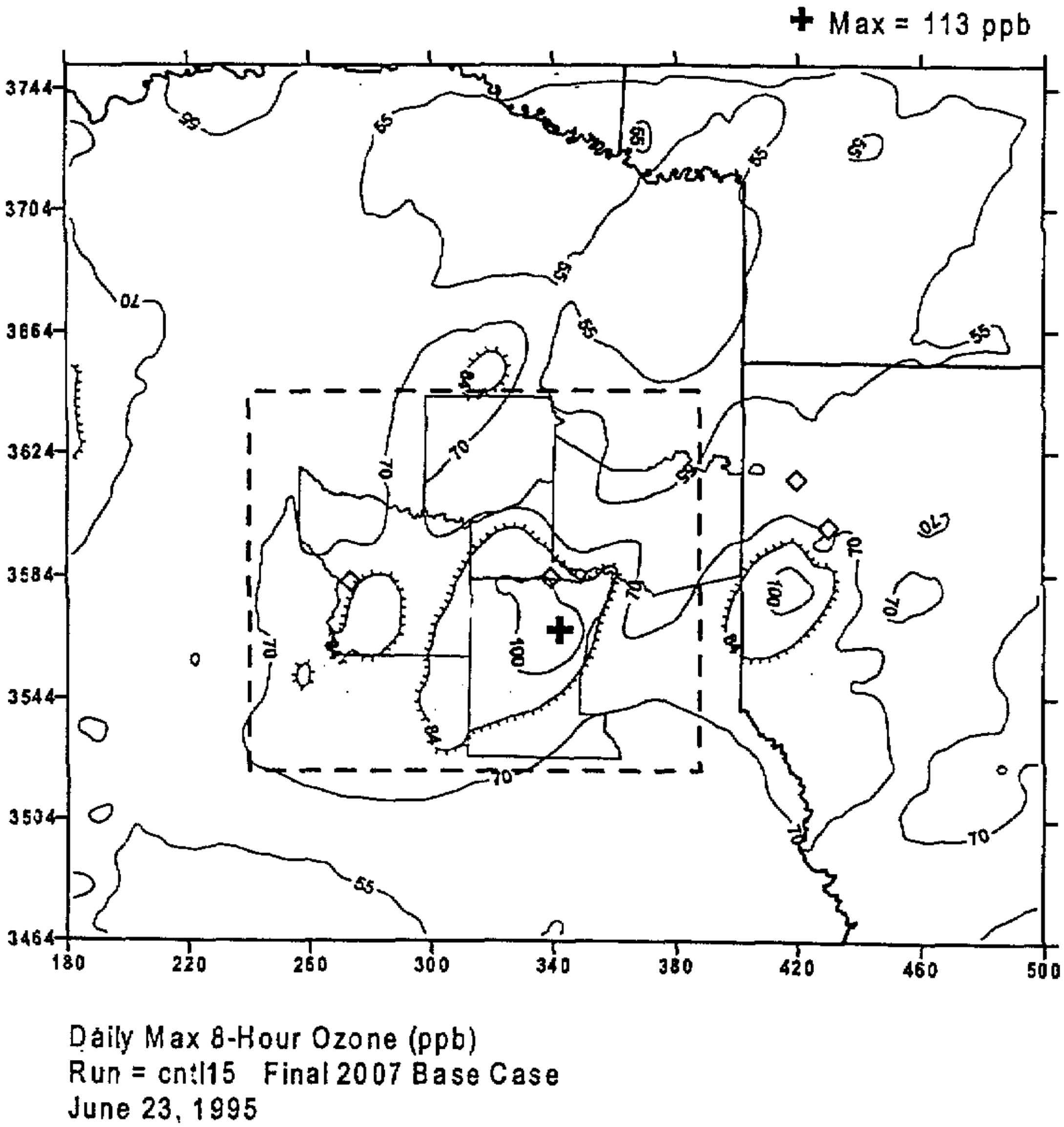


Figure 7-7. Isopleth of daily maximum 8-hour ozone for the final 2007 base case for June 23, 1995.

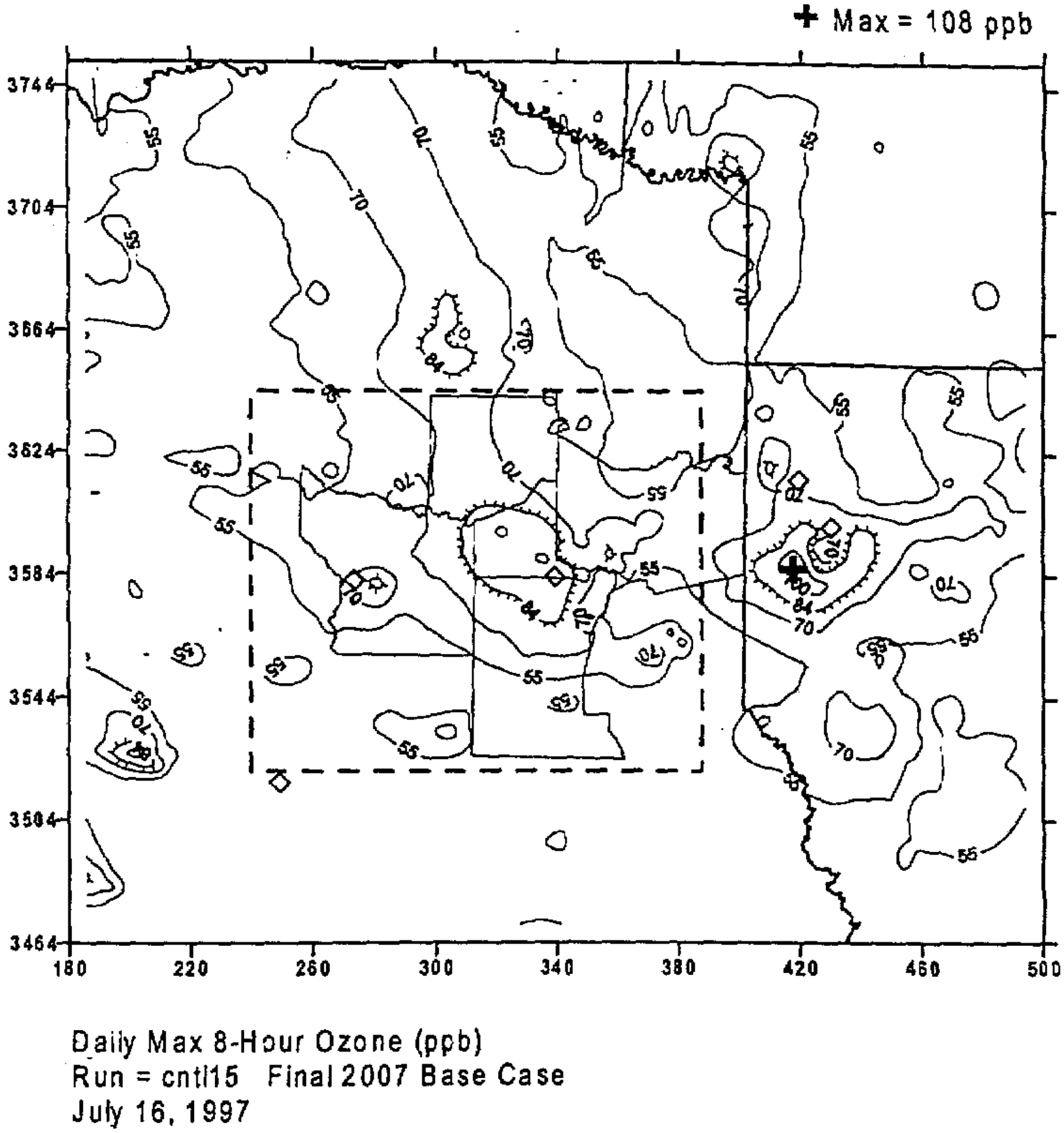


Figure 7-8. Isopleth of daily maximum 8-hour ozone for the final 2007 base case for July 16, 1997.

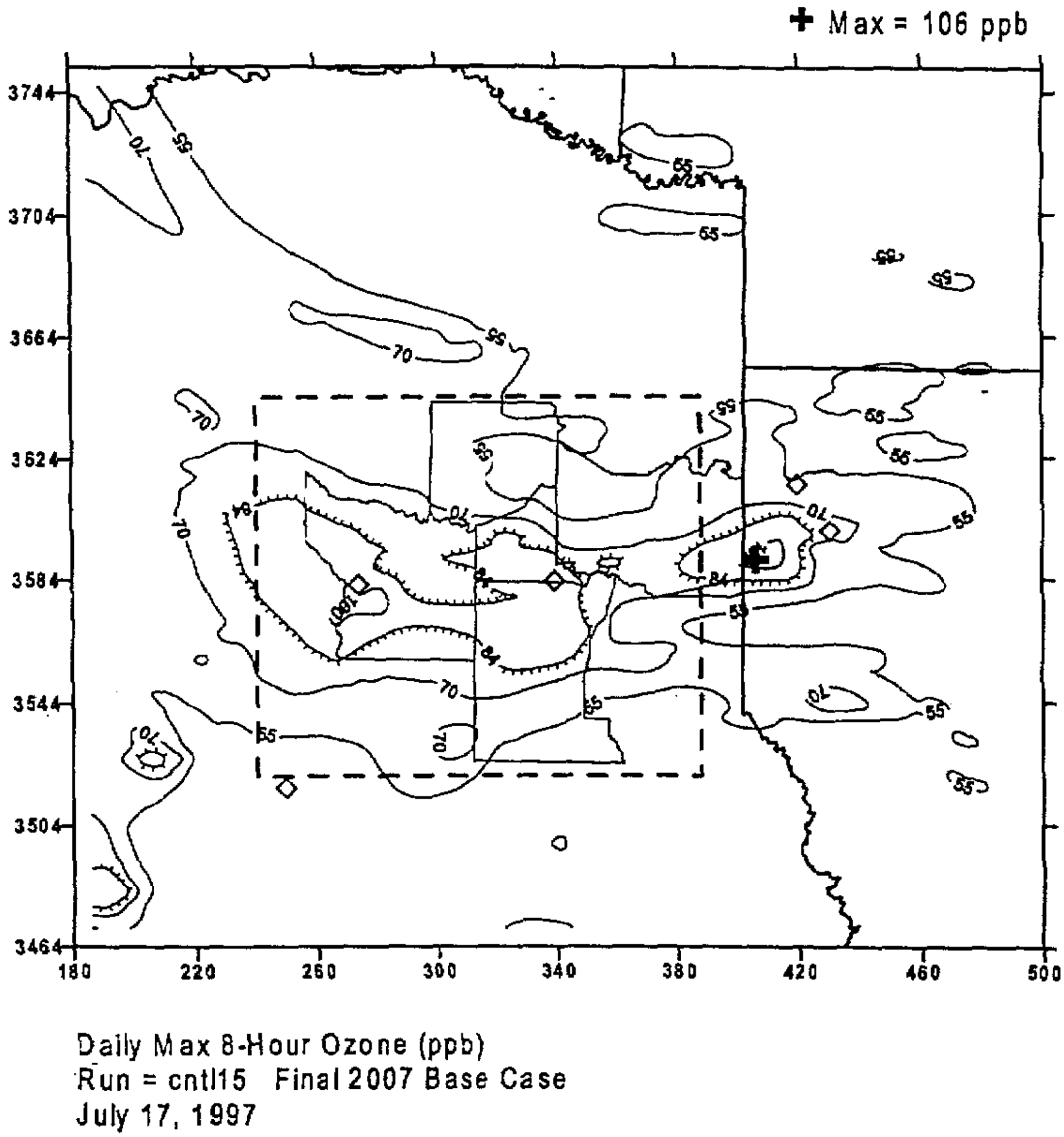


Figure 7-9. Isopleth of daily maximum 8-hour ozone for the final 2007 base case for July 17, 1997.

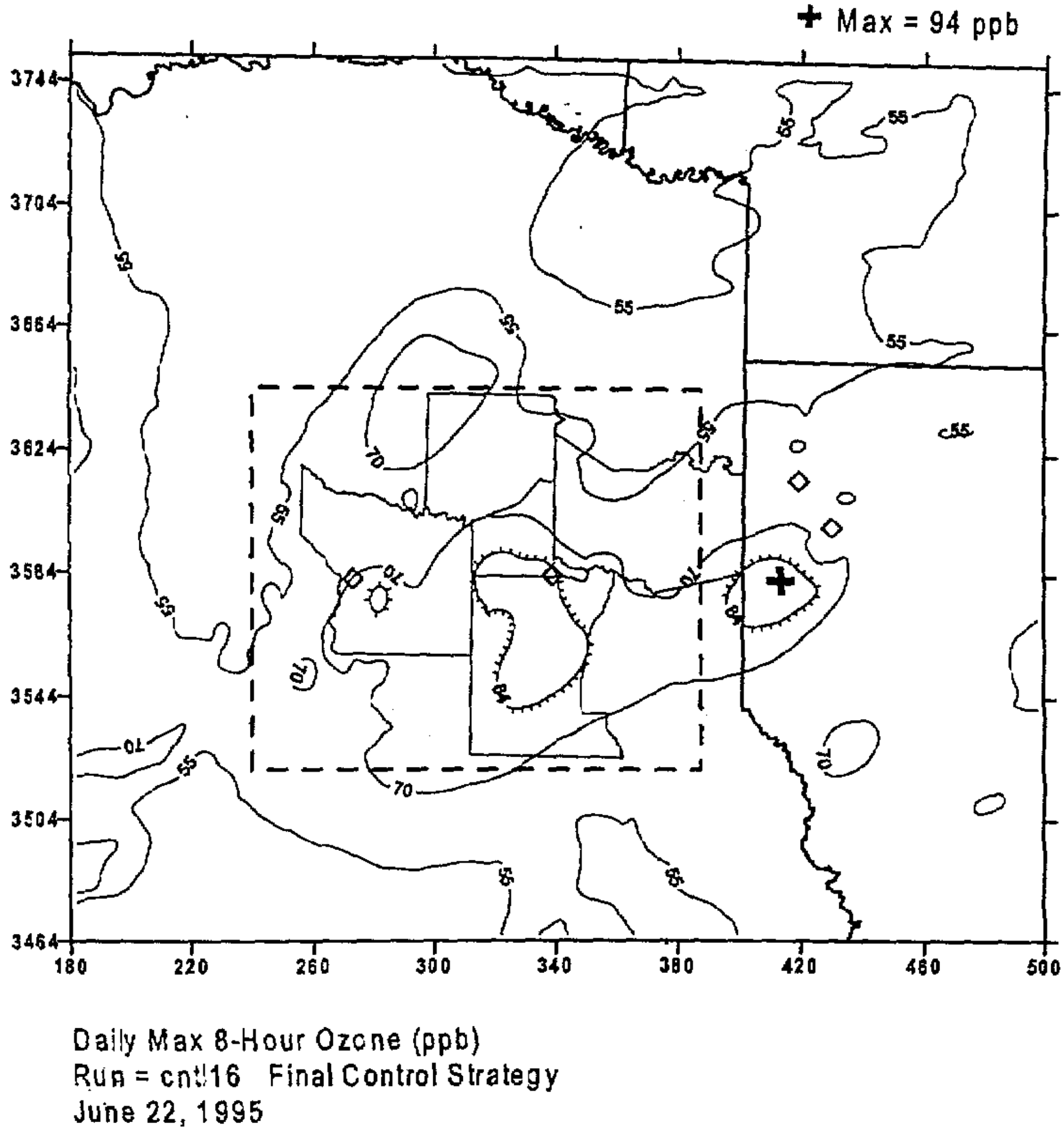


Figure 7-10. Isopleth of daily maximum 8-hour ozone for the final 2007 control strategy for July 22, 1995.

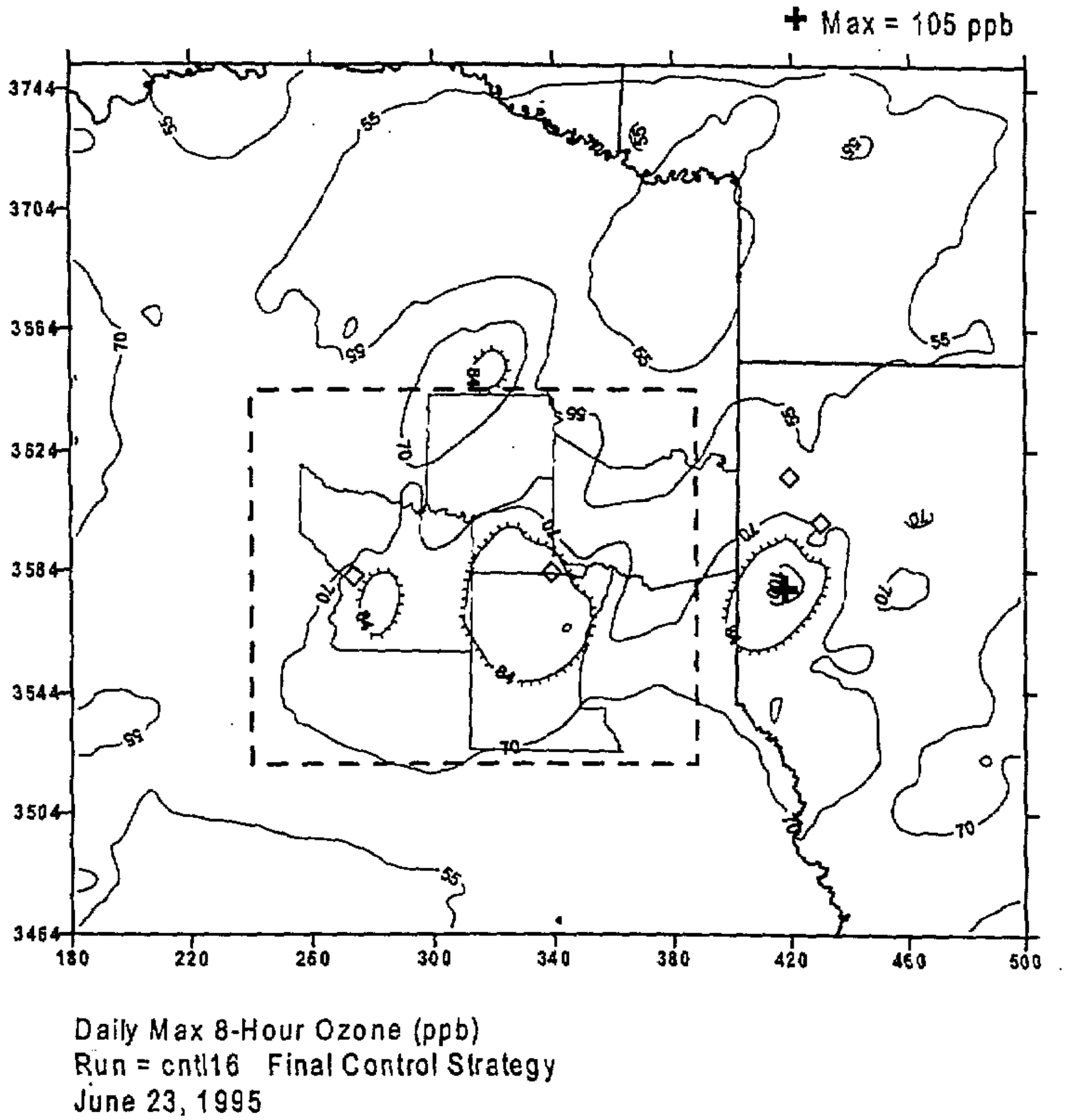


Figure 7-11. Isopleth of daily maximum 8-hour ozone for the final 2007 control strategy for June 23, 1995.

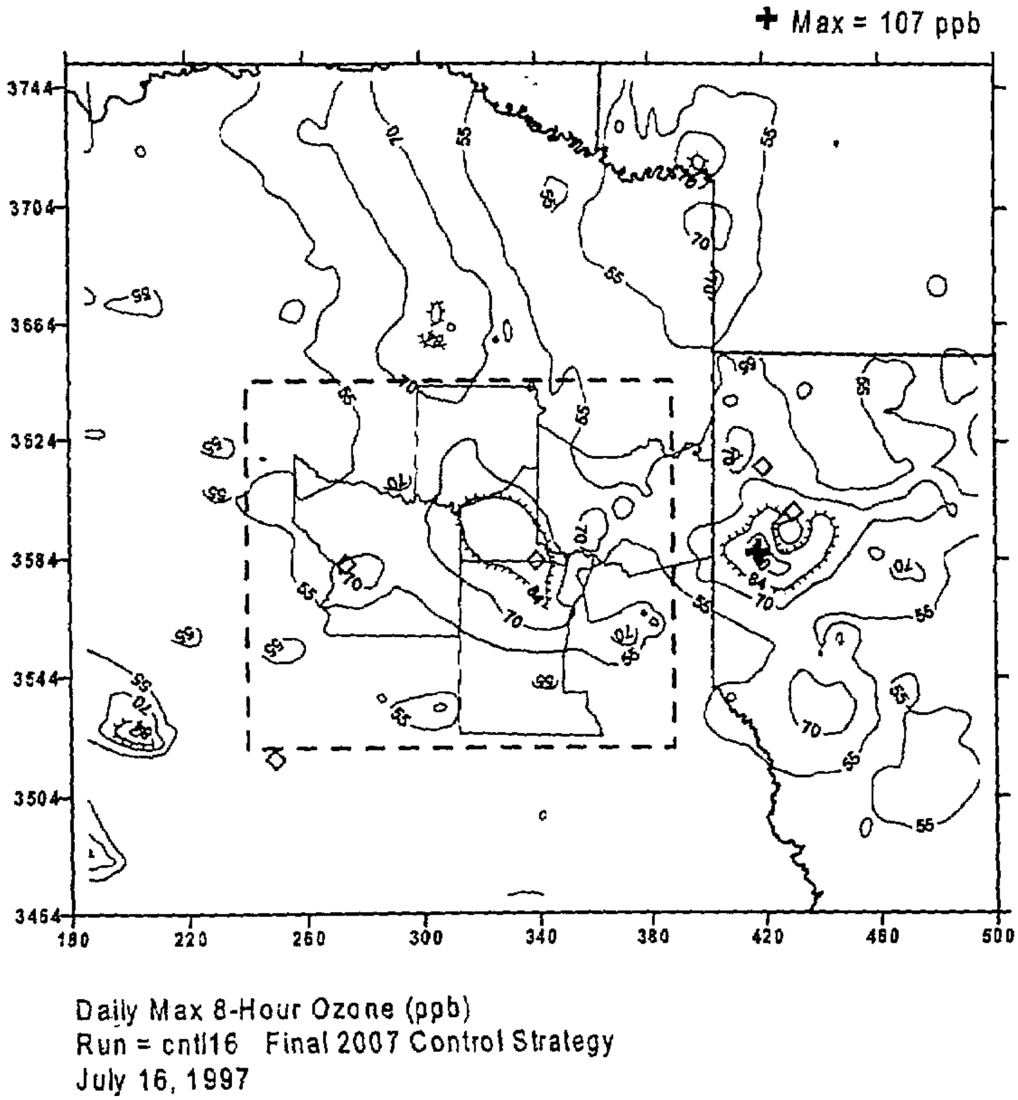


Figure 7-12. Isopleth of daily maximum 8-hour ozone for the final 2007 control strategy for July 16, 1997.

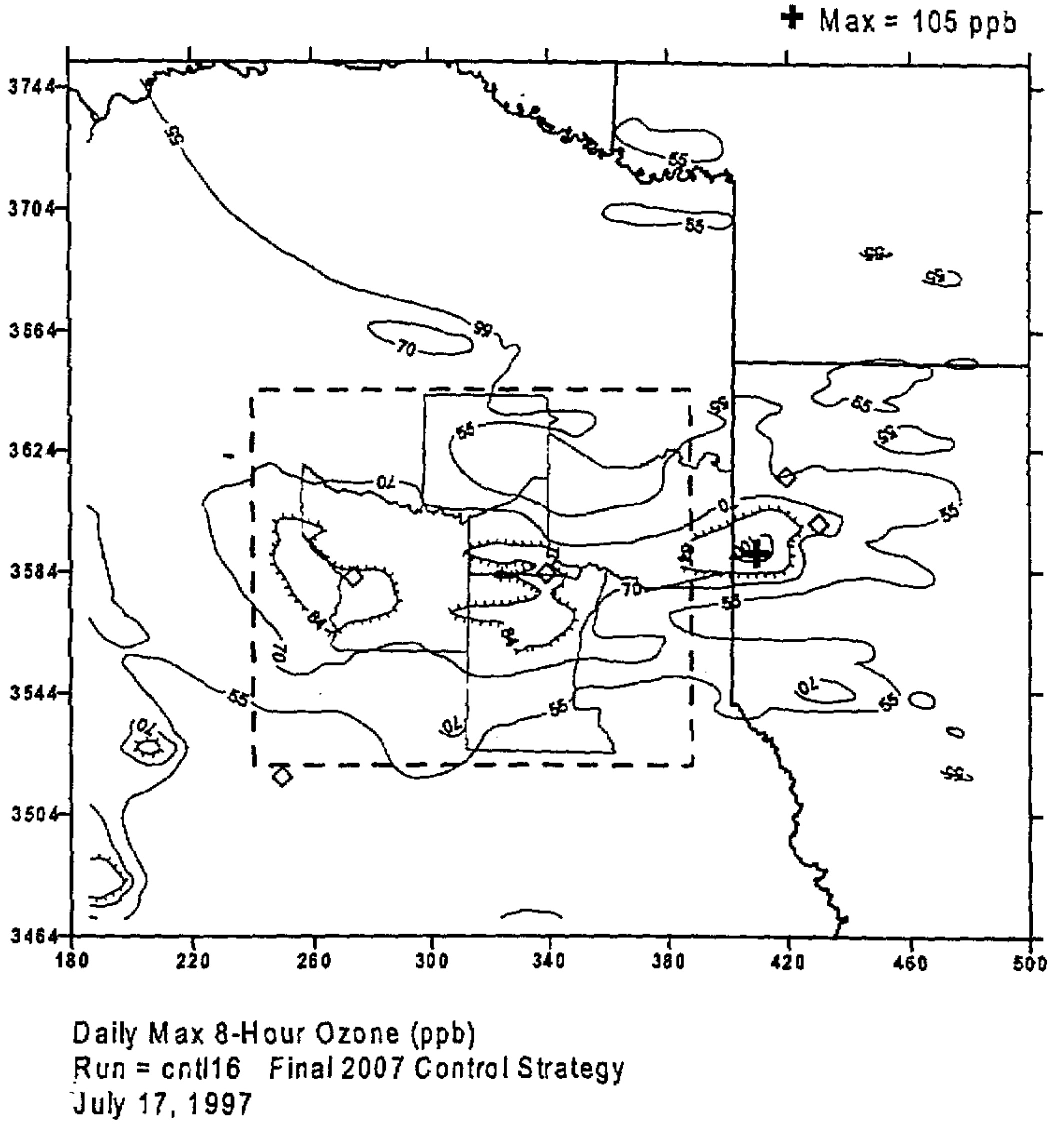


Figure 7-13. Isopleth of daily maximum 8-hour ozone for the final 2007 control strategy for July 17, 1997.

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